LIMITED COLLECTOR'S EDITION

FORZA MOTORSPORT 2

LIMITED COLLECTOR'S EDITION

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Microsoft game studios

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ForzaMotorsport.net

WELCOME

Welcome to the *Forza Motorsport™ 2* Limited Collector's Edition, your passport to the world of automobile racing, both simulated and real.

Forza Motorsport 2 players have two things in common: a passion for cars and racing, and a consuming desire to win, and this book is designed to feed that passion. In its pages you will:

- Get a behind-the-scenes look at what went into the making of the most detailed and immersive racing simulation to date.
- Find a wealth of information on the cars and tracks you can experience in *Forza Motorsport 2*.
- Learn about racing techniques that can fuel your success in *Forza Motorsport 2*.

THE VISION

An Interview with Lead Designer Dan Greenawalt

Lead Designer Dan Greenawalt is the keeper of the vision for the *Forza Motorsport* franchise. In this revealing interview Dan takes you behind the scenes for a better understanding of that vision, and of the physics that underlie this extraordinarily realistic auto racing simulation. From the tire physics that determine whether your car will stay stuck to the road or spin off the course, to his views on the automotive playground he is creating and constantly improving, to his emphasis on the joy of driving and his plans for the future of *Forza Motorsport*, this interview provides an intriguing look into the world behind the game.

"I envision Forza Motorsport *as the place where car lovers can gather to talk and argue about cars they like and racing they're interested in. I want to bring people with this passion together regardless of their other differences. My goal for the* Forza Motorsport *franchise is broad and inclusive."*

Q: *What are the physics behind the* Forza Motorsport 2 *racing simulator? What are the components of real-world racing you had to re-create?*

We spent a ton of time working on the physics. We used a lot of sources, but especially Milliken & Milliken's *Race Car Vehicle Dynamics*, a very reputable source on vehicle dynamics and tuning, with the graphs and the math as well as general theory. It's used a lot, not only for racing sims, but also by racing engineers. It was the single biggest influence for us; it became the way we spoke.

We made a technology demo with five meticulously researched cars to prove our physics engine. In many ways we were just trying to see what we could do. We poured six months into that demo, and the results were really incredible. There were no licensing agreements at this point, so we had cars rolling over, taking heinous damage, shedding parts—but you've got to make some allowances when you have agreements with fifty different premium car manufacturers. It was an all-star team of guys who had all been involved in one racing franchise or another—*Rally Sport Challenge*, *Project Gotham Racing*®, or *Midtown Madness*®. The physics was where we were at our purest, and I haven't seen many simulations that match the accuracy of *Forza Motorsport*.

Q: *So you slowly moved away from an entirely purist approach to an emphasis more on game design and gameplay.*

I love physics, and I like working on that aspect of the game in particular. While we were working on the demo, I was also working on the vision and the "pillars"—the features—that support that vision. I had to flesh it out from the top down. We all threw features at the wall to see what would stick. I worked to pull it all together and create a cohesive game design. We repeated this process for six months to get our vision honed. Not just the vision for *Forza Motorsport* version one, but for the franchise. This helped me get a better vision of where I want us to be in six or ten years—the game I want *Forza Motorsport* version six to be. This sort of forethought allows us to start planting little road signs in the game, minor features we could develop over time into major ones.

Q: *It sounds like your vision of the user experience shifted over time to become an online multiplayer experience, much more involved in version two.*

In many ways, *Project Gotham Racing* and *Forza Motorsport* are brother and sister products. We share technology; but more than anything, we share a charter to keep pushing the bounds of online play. Microsoft in general and our teams in particular believe that online play is where gaming is at today. We also believe that the most influential innovations in this genre are going to come in the online space. Our goal every time *Project Gotham Racing* or *Forza Motorsport* ships a new version is to make sure it just keeps getting better and better. We pushed the boundaries in the original *Forza Motorsport*; no game had so many scoreboards. We write to multiple scoreboards at once; no one had ever done that, and we had a seamless online to single-player Career mode. At the Xbox 360™ launch, *Project Gotham Racing 3* (PGR® 3) came out with even more fantastic online features, like Spectator mode. Now we're pushing the boundaries again with our Auction House, tournaments, and other new features. I really want to get us to a new way of experiencing racing games in the future, so we've got to keep making forward progress.

Q: *Tire simulation is a big part of the physics model, and people don't usually focus on that in racing games. What did you learn in trying to develop a realistic tire formula?*

We tried different tire models after our "green light" demo. We kept tuning the physics model, finding bugs, and working on it. New cars exposed new issues. We had two basic ways of expressing the tire physics. The traditional way that simulation racing games do this is Pacejka's Magic Formula—no joke, that's what it's called. It's got a whole slew of variables you tune and input, and it spits out friction values. But the cars didn't control the way we wanted and the results didn't mesh with a lot of our real-world data. I've had enough experience tuning with that formula that I can feel it at work when I play some racing simulations. It's not quite right, but it's close. Toyo put me in contact with their tire engineers. It was hard to understand the data they were giving me, and I had to ask a lot of questions, but they slowly brought me up to speed to where I could understand what their graphs and data were saying. Pacejka's formula is close, and really good in most situations, but not all, and not for transitions between states. It just doesn't feel right.

So we went to what could best be described as a table system. We have a table that linearly interpolates between the curves we have for different weights, tire pressures, and other variables. It's a very big, computationally difficult system. That's what was nice about Pacejka's formula when we were using it—it's very lightweight, where our approach is extremely heavy. That's why in *Forza Motorsport*, drifting, for example, is very real and very responsive. Drifting is all about weight transition, and you can control it with your throttle in *Forza Motorsport* because in our model the movement between those curves is very smooth and precise. We spent a lot of time getting it right. The tire model is amazing, but there are always things to improve. There are things in our physics model I'll want to improve forever.

Forza Motorsport 2 is a simulation, not a complete emulation—no one has ever done that, no matter what they claim. We can't completely emulate tire technology until the scientists learn it, and they haven't learned it all yet. Tires do some funky things. They've got load sensitivity, which involves non-Newtonian physics. A tire with a coefficient of friction of 1.0 at 500 kg actually develops a smaller coefficient of friction at 1,000 kg. With 500 kg on the tire, it might require a value of 500 kg force to push it. But with a 1,000 kg load, it might require a value of 800 kg force to push it. Understanding this is huge in understanding how tires function. It's a big deal to simulate this, though few people know about it. When I told the tire engineers, they were amazed we were doing it.

Q: *Please elaborate on why tires are so important in racing. Why do most people give more thought to parts upgrades than to tires?*

People tend to take their tires for granted; you see the tires on your car every day. But turbochargers and computer-controlled fuel injection systems are like alien technology to many folks—they're high tech and people don't see them every day. People think they understand everything about tires, and unfortunately tires are the part of the car they usually understand least.

Tire compounds are really crazy. We were at an American Le Mans Series (ALMS) race in Portland, Oregon, under very hot conditions, and saw how tires have a huge impact on racing. The science behind tire technology is always changing. We can get amazing performance out of tires, and the tires of today are much better than tires even just five years ago. That extreme rate of rapid iteration doesn't happen with turbos or many other engine technologies.

Your car talks to the road through four little tire contact patches, and it's how you manage those patches that makes everything work. After the ALMS race the manager of the winning team said the only reasons they won were their drivers and their tires, that both really came through in the heat.

The tires have many layers, all of which are meant to react to heat, torque, and force in various ways. If they do what they're supposed to do, they create the necessary coefficient of friction. When you start twisting that contact patch the tire winds up like a spring and gives you the slip angle required to hit peak friction. Doing that is a very complex process. It's interesting that different tire compounds, like a Y-rated tire, or a DOT-spec tire, or a racing tire, have very different characteristics. You look at them—they're just some rubber on a rim. It's not just the tread that gives tires their characteristics. Tread quality is essential, but it mostly comes down to the composition and construction of the tire. How sticky it is, how it reacts to heat, how the sidewalls flex, all make a huge difference.

Q: *Is there ever a reason not to use sticky tires?*

As someone who tracks his car, I can tell you that sticky is more expensive to buy and that you're going to go through them faster because they're softer, so you have to buy more of them. They also generally react badly to high heat. In that hot ALMS race, most teams were running on their hardest-compound tires. Because of the heat, those hard tires were getting soft and losing rubber, leaving "marbles" all over the track. On a cool day you would go with a softer compound and might only have to pit, say, once an hour. On a hot day you'd go with your hardest compound, and might also have to pit at the same rate. If you had stuck with the soft tires on that hot day, you might have had to pit twice as often. Also, on a hot day the softer tires might blister and fail. In *Forza Motorsport*, tire pressure increases as the tires heat up. This changes the contact patches and tire friction, and affects your handling.

Q: *What is the process of tuning more than 300 cars to make them feel right?*

We use roughly 9,000 individual variables just to define the physics for a single car—not including the tires, but for the variables that define the car and its upgrade parts (from spring rates, damping bump and rebound, to weight, aerodynamics, and so on). Even race cars that can't be upgraded involve 5,000 numeric values to define each car.

It all started when we were figuring out and iterating on the physics, and I was trying to determine whether there were patterns. We were reading Milliken & Milliken as well as other vehicle dynamics books and trying to identify how the cars relate to each other. Basically, we were developing a math model for tuning the cars. The hardest thing is, you can't find, for example, spring rate data for all 300 cars. You're lucky if you can get it for 20% of them, from the manufacturers and from research. Sometimes you can get that kind of data on fan Web sites, which can be freaky that way. Sometimes we contacted the spring manufacturers, not the car manufacturers. The manufacturers we contacted were based on the continuum of all of the cars, so we could get a really even spread of data on low-end cars to high-end cars to race cars, finding out about progressive springs versus linear springs, and so on.

Then we looked at ride height, the weight of the car, and what we call the "goodness rating," from reading reviews and learning a lot about each car. We ranked the cars based on their "goodness," and arranged those values into buckets. For example, we might put a Ford Focus SVT a little lower than a Subaru WRX STi. When we set the spring rates for those cars, and we don't have the actual spring rates for them, we use a formula, a mathematical model, to automatically tune those numbers for us. Then we put in critical damping, and offset damping with "goodness," ranking cars by region. A lot of this we call "automagic"—it's our voodoo magic that we do in the game, and it's the only thing that makes it possible to tune 9,000 numbers on 300 cars.

Proving that this automagic model could work to tune the cars was a big part of our getting the green light for version one. And there's a ton of testing that goes on. We list and graph the numbers we get, looking for anomalies, and then we test the cars by hand. For example, one may come out with a really loose spring rate. Sometimes we find that our formula isn't taking weight distribution into account as well as it should. Then we rework the formula, reexport all the cars' values, and retest. That's a lot of systems—engine systems, such as turbo pressure, rpm, inertia, and so on. Some things we get to research a lot, like all of our stock turbo pressures. We went through and tested them, and made sure that they were in the right stack rank relative to each other and that their results in the game matched our research and knowledgebase.

Q: *For the original* Forza Motorsport*, racing driver Gunnar Jeanette made some suggestions about cars he had driven, and you were able to change some numbers on the fly to make the car more realistic. Is that something you're doing for* Forza Motorsport 2*?*

There are two sides to it. Some of the cars drive the way they do because it's completely predictable. You look at the car's behavior and it's easy to see why it behaves that way. If it understeers and you see that it's front-weighted with no downforce, all the tires are the same size and its spring rate is tighter on the front, obviously it's going to understeer. In a front-drive car with 60% of the weight on the front wheels, it's just physics that the car will understeer. So there are a whole bunch of characteristics people comment on—"You really got that right!" I say, "We didn't have to get it right—the physics got it right!"

Q: So we're really talking about hand tuning.

After the automagic has done its thing, then you go in and hand tune. For instance, getting the nuances of the suspension right is less about oversteer and understeer and more about controlling the car with the throttle through a turn; how getting onto, off of, and back onto the brakes creates oversteer; how braking and throttle techniques affect the car. We've got a really good team—guys who are rally drivers, guys who have driven all kinds of cars. So we start tuning that way. But inevitably there are cars no one on the team has driven, like the Lancia Stratos. We had trouble finding reviews on it; we just knew it was a famous rally car, but our physics got a ton of that stuff right. You start putting in the weight distribution, the size of the car, its moment of inertia, and it starts getting better and better.

Q: How do you handle implementing upgrades? When does the upgrade variable come in?

Some of the upgrade variables are researched heavily in order to create the model. The issue is that our Level 3 upgrades are full racing upgrades, as if you had a million dollars to burn, which very few people have, especially on a lower-class car. No one is going to spend so much upgrading cars like that, so we have some cars people don't race much, and have no idea how much power that engine can really make. So we have to use some math and our model to figure it out. The car has a certain displacement and configuration, it's a certain size, has a certain rpm redline and top speed, and we take all those things and put them together and come up with what we think is its theoretical maximum torque and horsepower. But believe me, gas velocity out of the valves and headers can be a real pain to estimate.

Q: Since you have to account for things you can't find in reality but that can exist in the sim, are there times when the potential for so many car modifications seems too crazy and unbelievable even though the math says the model is right?

When I was developing the franchise vision, I hit on the idea early that this is an automotive playground, a sandbox. We could have gone the route of a super-credible, licensed parts catalogue. We could have said, "Exactly what parts really are available for, say, the Mark II GTI? Oh, these parts are available in the real world—okay, then that's exactly what the player will get—no more and hopefully no less. It's sort of limiting for cars that for one reason or another have never gotten a lot of race R&D in the real world.

Also, we could have exposed the player to the money pit and no-win situations that define tuning in the real world. One turbo is more reliable; one has better low-end spool-up. Why use this suspension part instead of that one? One is better at low-speed bump compression and the other is better at high-speed bump compression. Which one is better? Neither, but one is more expensive. That's real tuning. That's what I've got to do on my own car. That's why my "check engine" light is always on for one reason or another and my fenders rub during track days.

I want to make this a sandbox or playground where people can safely experiment. I want to invite people in and teach them a ton of things, but not require them to already know it all. If we throw them into the deep weeds and expect them to already know everything there is to know about cars and upgrades, most won't even know where to start. I didn't feel it would be very inviting. Moreover, it wouldn't be as good a place for people to learn. If you buy a car that in the real world doesn't have many upgrade options or a tuning community, we'd have to say, "Sorry, this car doesn't get any substantial upgrades." It's not that parts couldn't be made for those cars; there simply isn't demand for them in the real world.

What we want to do is make it all about real-world potential: "Hey man, if you had three million dollars and really like a particular car, you can go ahead and upgrade it. We'll do the legwork to make sure the results are plausible and rooted in real science." This makes our upgrade system a really cool playground where people can learn about cars and upgrades.

Q: Someone in the* Forza Motorsport *community tuned an Integra to go over 250 mph, so I guess in the sandbox it's theoretically possible?

It's hard to know. We simulated cars driving on an open plane at their top speed and tried with gearing to match theoretical top speed in our database. In some cases we ended up tuning drag coefficient and driveline losses quite a bit. What's important to me is that we really do our homework, really do our math to figure it all out, so if you see it in the *Forza Motorsport* games, it really is possible.

Q: So it's a balance between the sandbox element and also being credible.

It's all about being credible. It's whether or not our math shows it could be done in the real world given time, money, and expertise. We look at the math and say, "Wait a minute—with that frontal area and drag, you need this much power to put enough torque onto the ground to reach that speed"—it's mathematical. Sometimes I don't believe our results and we have to test them. Sometimes we have to rework the system to provide better results.

Q: *What do you think people responded best to in the original* Forza Motorsport*?*

First and foremost, *Forza Motorsport* is a fantastic simulator. The thing we really did well was the thing we had to do well, the thing we're always going to have to do well: create a fun, deep, and rewarding driving experience. We had to create an experience that was fun to drive and easy to get into while maintaining a deep and rewarding path to mastery. You pick up *Forza Motorsport* and if you're not really good at it, you can use driving assists. We don't dumb the physics down; we bring the player up using assists. Players can start turning them off one by one as they advance down the path to mastery. I want *Forza Motorsport* to have all the depth of a great sim, but I also want people to be able to play it. Once you start turning the assists off, you can start expressing yourself in your driving, the way you can in the real world. You can be really fast, you can drift, you can be stylish, and you can recover when you start to screw up. Once you get skilled at the game, it no longer feels like a razor-thin edge, where if you get any yaw going in your car—goodbye, you're out of here. You can start playing with the physics and making the car obey your every command. In the real world it all comes down to sensitivity and timing. You see a guy like Juan Pablo Montoya in a car with racing slicks. Racing slicks are the most intolerant tires there are, and he can still get the car's back end out a little bit and whip it back in and not spin out because he can feel it and he's on it instantly. You can do that in *Forza Motorsport*. We can build a game around the player's path of mastery, but at heart *Forza Motorsport* is a fantastic simulator, and it's a fun simulator.

Q: *Now that version two is wrapped up, as the visionary, what do you see down the road for the* Forza Motorsport *franchise?*

We've only built a small percentage of the game I see in my head. In some instances, the technology isn't there yet. In others, we just haven't had time to fully realize the experience I'm chasing. As before, we've made little road signs about what's coming in the future. In a lot of ways it's about experimentation. We try little bits of things to see how people react, whether people have fun and maybe even learn a thing or two. It's one thing to design something and proclaim, "People are going to love this!" It's another thing to put a little bit out there and ask, "How does this taste?" Give them a little sample. It's a chance for me to watch them. People say they like a feature or don't like it. Players are rarely good at articulating what they like or don't like, but they are spot on at identifying whether or not they are having a good time. To learn what they're really feeling and enjoying, it's important to watch them, watch how they play. They might say, "Oh, I'm really frustrated with this!" But they're smiling. Or they might say, "I'm really enjoying that," but it looks like they're fidgeting, like they want to leave. Often there is some other aspect of the experience that they do not perceive that is having a greater effect than what they identify. It's our job to sniff that out.

Q: *So you're going to be perfecting that fun-to-drive experience for every version of the game?*

What I'm trying to capture is the joy of being a race car driver and sports car enthusiast, not the experience of having to pay for fuel, pay for tires, blow your engine, get scammed by a shady tuner, and so on. We don't want to simulate the struggle to get a ride with a team, because that's not the joy of driving. There are people who may want that game, but that's not what this game is about. This game is about the joy of collecting, customizing, and driving amazing cars and learning how to get good at it. We don't just dumb the physics down. We let the player experience the car in its full glory and supplement their skills with powerful assists. We've got to build a game that grabs people. Where car collecting, car upgrading, car customization, car owning, car trading, and living in a community and interacting with other people are all great things to do. At any moment you can go in there and have a great experience. I want to get gamers excited about cars, and car people excited about games.

Q: So the game is really built around the core experience—the joy of driving.

The driving experience is definitely the core mechanic of the game—it's what we had to get right. However, at the heart of the vision, the grain that got this whole thing growing is "car lust," a passion for cars. That's what sprouted the simulation, sprouted the upgrades and customization, what sprouted this community. Everything came from that. So simulation is the core mechanic, but it's not the seed of the game. The seed is that emotional response you have when you see an amazing car on the street. That's car lust.

Q: Can you give us a hint of what you're thinking about for Forza Motorsport 3? What would you like to add to the experience that will significantly change it?

For me the future of gaming is all about pushing online and community. Online gaming plays to that seed, that car lust, but not everyone is good at driving. Having car lust doesn't mean you have a big bank account, doesn't mean you're a male, doesn't mean you're good at driving, doesn't mean you're a dexterous gamer with fast reactions. That nugget of car lust is way more universal. It's shared by a lot of people in all walks of life. So for me, the future is about getting more people who share car lust to experience the game; bringing them together to play. They don't all have to be driving; they can be doing different things to be part of the community. They can be equally valued in the community if we give them the right tools. Even if I like muscle cars and you like European cars, we've still got something to talk about. You may be more dexterous, a really good sim racer. Maybe I'm not so good at it. But let's say I'm really good at painting, or tuning, or strategizing, or getting people together in a community. There are a lot of skills you can use to be part of the *Forza Motorsport* community. It's all about giving a diverse group of people brought together by "car lust" the tools they need to add value in the community.

Q: So races are won by collaborative effort?

My goal is to look at the kinds of things people can be good at. If they have that car lust, they can find ways to be successful and rewarded and valued in the community. While in a lot of ways this resembles a racing team, I'm not interested in simulating a racing team per se. What I want is for someone who isn't necessarily a great gamer but who loves cars, to feel they should be playing *Forza Motorsport* to connect with other car lovers. When a new car comes out and people read about it, they should be able to drive it in our simulation.

I envision *Forza Motorsport* as the place where car lovers can gather to talk and argue about cars they like and racing they're interested in. I want to bring people with this passion together regardless of their other differences. My goal for the *Forza Motorsport* franchise is broad and inclusive.

CAR MANUFACTURERS

In creating a very large stable of cars for our players, the *Forza Motorsport* team has worked with fifty car manufacturers from all over the world. Each manufacturer has a history of its own, and each has made its contribution to the evolution of the automobile.

In this section of the *Forza Motorsport 2* Limited Collector's Edition book you will learn about the following automobile manufacturers:

- Acura
- Aston Martin
- Audi
- Bentley
- BMW Motorsport
- Buick
- Cadillac
- Chevrolet
- Chrysler
- Dodge
- Eagle
- Ferrari
- Ford
- Honda
- Hyundai
- Infiniti
- Jaguar
- Koenigsegg
- Lamborghini
- Lancia
- Lexus
- Lotus
- Maserati
- Mazda
- McLaren
- Mercedes-Benz
- MINI
- Mitsubishi
- Nissan
- Opel
- Pagani
- Panoz
- Peugeot
- Plymouth
- Pontiac
- Porsche
- Proto Motors
- Renault
- Saab
- Saleen
- Saturn
- Scion
- SEAT
- Shelby
- Subaru
- Toyota
- TVR
- Vauxhall
- Volkswagen
- Volvo

ACURA

In 1986, Honda Motor Co. of Japan started producing the Acura line of cars for several markets, including the U.S., becoming the first of three Japanese manufacturers to launch separate luxury brands. The first Acura models—the Legend, Integra, and especially the avant-garde NSX—set the tone for the new brand, with a dual emphasis on luxury and performance. The late Formula One champion Ayrton Senna consulted on the NSX's suspension and chassis tuning, and the car was both a stunning performer and suitable for everyday street driving.

Acura also produced some very desirable special models with an extra emphasis on performance. The 195-hp Integra Type-R features a race-tuned suspension, high-performance tires, powerful brakes, and special seats. The NSX-R, introduced in 1992 for Japan and Europe and updated in 2002, is a lightened version of this already super car. Its 290-hp V6, aggressive suspension, and improved aerodynamics allow it to compete successfully against more powerful cars.

2001 Acura Integra Type-R

ASTON MARTIN

This British manufacturer of hand-crafted high-performance sports cars was founded in 1914. After early competition successes (the Aston name was derived from an English hillclimb course), Aston Martin focused on racing during the 1920s and 1930s. In 1947, Aston Martin was acquired by David Brown Limited, which launched the long line of "DB" high-performance sports cars for which the company is best known. The series began with a few examples of the Two Litre Sports/DB1 in 1948 and the DB2 in 1950. Racing versions of the Aston Martin sports cars achieved great racing success during the 1950s, culminating in a first-place finish at the Le Mans 24-hour road race in 1959.

In the 1960s, Aston Martin decided to concentrate on road car production, creating perhaps its most famous car, the DB5, in 1963. This sports car began a long relationship with secret agent James Bond after appearing in the film *Goldfinger* in 1964, and gained the company and its cars many new admirers. The DB line of sports cars continues to this day, with the award-winning DB9. Aston Martin returned to motor racing in 2005 with a racing version, the DBR9. The current three-car lineup also includes the V8 Vantage and the Vanquish S.

2001 Aston Martin Vanquish

AUDI

August Horch, who founded a car company under his own name in 1899, started Audi (the Latin translation of Horch) in 1909. Early Audis were luxurious, and also had some competition success. In 1932, four German car companies (Audi, Horch, DKW, and Wanderer) merged to form Auto Union; the four linked rings of the current Audi logo represent the four companies. Along with racers from Mercedes-Benz, mid-engine Auto Union race cars designed by Ferdinand Porsche dominated motor racing in the 1930s.

In 1964, Volkswagen acquired the company and revived the Audi name. The car that launched Audi's modern reputation as a technology leader and maker of advanced, competitive cars was the four-wheel drive Audi quattro in 1980. The Group B racing version of the Audi 200 quattro dominated the TransAm series in 1988, and sent competitors back to the drawing board. Audi's popular A4, A6, and A8 series cars first appeared in 1996. The high-performance all-wheel-drive S-series versions of these cars have been successful in amateur competition, and Audi's Le Mans Prototype race cars have played a dominant role at the top level of motor racing, led by the 550-hp R8, which won the 24 Hours of Le Mans three times in a row. In 2006, Audi introduced its latest Le Mans Prototype, the Diesel-powered R10 TDI, which won in its first outing at the Twelve Hours of Sebring, as well at the 2006 24 Hours of Le Mans.

2006 Audi RS 4

BENTLEY

W. O. Bentley founded this legendary British marque in 1919, and decided to prove and promote his cars through competition. In 1924 a 3-liter, 4-cylinder Sport model won Bentley's first victory at Le Mans. In 1926–1927, Bentley introduced the 6.5-liter Speed Six and the sportiest Bentley, the 4.5-liter 4-cylinder. This was Bentley's golden age, with four consecutive Le Mans wins in 1927–1930 shared among the three models. The drivers, who came to be called "The Bentley Boys," were amateur sportsmen who drove fast and lived glamorously. Their big, British racing green Bentleys stood out for both performance and size, dwarfing most continental racers. Ettore Bugatti compared them to trucks, commenting that Bentley built "the world's fastest lorries," but Bentleys quickly built a reputation as the world's best sports cars.

With the Great Depression Bentley sales plummeted and in 1931 the company was sold to Rolls-Royce. For many years most Bentleys were Rolls-Royces with a different radiator shell. One major exception was the 1952 R Type Continental, a beautiful 120-mph, four-seat fastback that still turns heads today. In the late 1980s, Bentleys again emphasized performance with turbocharged power and roadholding to match. This transformation continued in 1998 when German manufacturer Volkswagen bought Bentley and invested heavily in new models. After a seventy-one-year lapse Bentley returned to racing with the Speed 8 Le Mans Prototype, taking third place in 2001, second place in 2002, and winning a sixth Le Mans victory in 2003.

2004 Bentley Continental GT

BMW MOTORSPORT

German automobile and motorcycle manufacturer BMW (the Bavarian Motor Works) began as a manufacturer of aircraft engines during the First World War, so the BMW logo, a roundel of alternating blue and white quadrants, represents a whirling aircraft propeller. The company produced its first car in 1927. By the late 1930s, BMW was building two pre-war classics, the 327 sedan and the 328 roadster.

After WWII BMW resumed automobile production in 1952, and produced the legendary 507 sports car in 1957. During the 1960s, BMW launched a series of increasingly sophisticated models. With their independent suspensions, front disc brakes, and emphasis on performance, BMW established its reputation as a maker of cars for driving enthusiasts. In 1972, BMW created its racing subsidiary, BMW Motorsport, which started producing the "M" high-performance versions of standard BMW models in 1979.

2002 BMW Motorsport M3-GTR (street version)

BUICK

David Dunbar Buick, a Scottish immigrant to the U.S., started making gasoline engines in 1899 and built his first car in 1902. He incorporated Buick Motor Company in 1903, which was taken over the following year by William Durant, later the founder of General Motors. By 1908, Buick® was producing about 8,000 cars annually, more than any other manufacturer. Buick pioneered the overhead valve engine and started a racing team featuring Louis Chevrolet. Early racing successes and a growing reputation for reliability solidified Buick's reputation. It became the first brand in the General Motors stable in 1908.

By the mid-1920s, Buick was producing more than a quarter-million cars a year, but its sales slumped early in the Great Depression. In 1936, stylish new models conceived by GM design chief Harley Earl revived Buick's popularity. During WWII, Buick built aircraft engines and military vehicles. Buick sales boomed during the 1950s heyday of big, stylish American cars. In the 1960s and 1970s, Buick introduced smaller, lighter, more innovative cars powered by V6 engines. In the 1980s and early 1990s, Buick again emphasized racing and competition, building engines for the Indianapolis 500 and performance cars powered by turbocharged V6s, especially the 1987 Regal GNX "muscle car." Buick continues to be a mainstay of the General Motors Corporation today.

1987 Buick Regal GNX

CADILLAC

Cadillac Automobile Company was founded by Henry Leland in 1902. In 1903 its first production car was an instant success, and in 1909 Cadillac® became General Motors' prestige brand and a leading innovator. Cadillac introduced fully-enclosed bodies in 1910, the first reliable electric starter in 1912, and a powerful V8 engine in 1915. These and other innovations in the 1920s, including a better-balanced V8 engine, a synchromesh transmission, and safety glass, enhanced Cadillac's reputation. In 1930, Cadillac introduced luxurious V16- and V12-powered models. Soon Cadillac offered independent front suspensions (pioneered by Chevrolet) and automatic transmissions.

During WWII, Cadillac V8s and transmissions powered American tanks. After the war, Cadillac combined technical innovations and styling, introducing a trendsetting overhead-valve V8 and tail fins. A British Allard powered by the Cadillac V8 finished third at Le Mans in 1950, and a stock Cadillac coupe finished 10th, proving how potent the new engine was. Over the years Cadillacs grew larger and more flamboyant, but in 1992 Cadillac introduced the twin-cam Northstar V8, renewing an emphasis on performance. In 2000, Cadillac returned to Le Mans with its Prototype racer, the LMP02, which it also campaigned in the American Le Mans Series. The 2003 CTS and the 400-hp CTS-V race car continue Cadillac's return to performance-oriented production cars.

2004 Cadillac CTS-V

CHEVROLET

In 1911, William Durant enlisted Swiss-born racing star Louis Chevrolet to design a car with broad appeal, and in 1912 the new Chevrolet Motor Car Company introduced its first sedan with a long list of standard features. In 1915, Chevrolet® introduced the 490 (priced at US$490) to compete directly with the best-selling Ford Model T, and it was an instant success. By 1927, Chevrolet was the most popular American car. When WWII started, the division was building over 1.5 million vehicles per year. After the war, Chevrolet reclaimed its place as the best-selling brand with popular features including automatic transmission and power brakes, seat, and windows.

In 1953, Chevrolet launched what would become America's most successful sports car, the Corvette, and when Chevrolet introduced its legendary small-block V8 two years later, it quickly found its way into the Corvette. The 1963 Sting Ray with its fully independent suspension added to the Corvette's popularity and competitiveness. The compact, sporty Camaro debuted in 1967, and became another instant best-seller. Today, Chevrolet continues to offer a car for nearly every market niche, and the company's nickname, "Chevy," shows the popular impact of this brand.

2006 Chevrolet Corvette Z06

CHRYSLER

In 1910, Walter P. Chrysler became works manager for Buick Motor Company, and then vice president of General Motors in 1919. In 1925 he founded Chrysler® Corporation, and rapidly expanded it to become a serious rival to General Motors and Ford. Chrysler started Plymouth® and DeSoto, and in 1928 acquired the large and successful Dodge Brothers Corporation, which had sold two million cars under its own name. In 1934, Chrysler introduced the Airflow, a streamlined car that pointed to the future, but found few buyers. By 1937, Chrysler was building more than a million cars a year.

In 1951, Chrysler introduced its powerful "Hemi" V8, which was continually developed in the 1960s, growing in displacement from 331 cubic inches (5.4 liters) to 426 inches (7 liters) to become a major force in American automobile racing. In 1998 the Chrysler Corporation merged with Daimler-Benz AG to form DaimlerChrysler. Two products of this merger appeared in 2004. The Chrysler Crossfire® sports car shares many components with the first-generation Mercedes-Benz SLK. The Crossfire SRT-6 is a supercharged high-performance model with a 320-hp version of the standard V6. The Chrysler ME Four-Twelve, produced as a prototype, is a 250-mph, V12 powered mid-engine supercar billed by the company as the "ultimate engineering and design statement from Chrysler in terms of advanced materials, aerodynamic efficiency, and vehicle dynamic performance."

2006 Chrysler Crossfire SRT6

Like the Wright brothers, the Dodge brothers (John and Horace) began in the bicycle business, but around the turn of the twentieth century they switched to making automobile parts. From 1902 until 1914, when they started the Dodge Brothers Motor Vehicle Company, the brothers made parts for other manufacturers, including transmissions for Olds and engines for Ford. The engine deal netted them a ten percent interest in Ford Motor Company, which they sold back to Ford in 1919 for US$19,000,000. Dodge Brothers cars, with their all-steel bodies, rugged construction, and attention to detail, quickly built a reputation for "dependability," a word invented by a copywriter to describe them. After 10 years the brothers had built a million cars, and made another million by 1928, when they sold their company to the Chrysler Corporation.

Some of the most potent post-WWII Dodges, including the late-1960s Chargers, were powered by a 426-cubic-inch (7-liter) version of Chrysler's Hemi V8. In 1992, Dodge introduced the V10-powered Dodge Viper, a muscular retro sports car that has competed internationally, winning in its class at Le Mans and in the GT2 World Championship. Dodge has also produced performance versions of its small cars, notably the Neon-based SRT4 and the PT Cruiser GT Turbo. For 2006, Dodge reintroduced a Hemi V8-powered Charger, the SRT8.

2006 Dodge Charger SRT8

Eagle was the last reincarnation of American Motors Corporation (AMC), which had been formed by the merger of Hudson Motorcar Company and Nash-Kelvinator in 1954. In 1970, AMC acquired the Jeep name and facilities from Kaiser-Willys, but fell on hard times in the 1980s. After a brief collaboration with France's Renault, AMC was sold in 1987 to Chrysler Corporation, which ran AMC as its Jeep/Eagle division from 1988 to 1998. Chrysler's goal was to attract driving enthusiasts and would-be buyers of imported cars.

The division's most successful model was the sporty Eagle Talon, based on the Mitsubishi Eclipse. The Eclipse and the Talon, as well as the Plymouth version, called the Laser, were manufactured in Normal, Illinois by a Chrysler/Mitsubishi joint venture called Diamond Star Motors. From 1990 to 1998, these two-door, front-wheel drive hatchbacks (powered by a Mitsubishi 4-cylinder engine and turbocharged in the all-wheel-drive TSi model) were Eagle's best-selling car. Its success wasn't enough to save Eagle, and Chrysler stopped producing the brand in 1998.

1998 Eagle Talon TSi Turbo

FERRARI

Ferrari is a legendary name. For 60 years this elite Italian manufacturer has built some of the world's fastest and most beautiful cars, and has won innumerable races. Founder Enzo Ferrari drove his first race in 1919, and started Scuderia Ferrari in 1929 sponsoring amateur drivers, many competing in cars built by Alfa Romeo. In 1947 he founded Ferrari and started the string of stunning cars and racing victories that continues today. In a sense, Ferrari's intent was to build a race car that could also be used on the street, but from the beginning Ferrari built sports and Grand Touring cars to finance its racing efforts.

The first postwar Ferrari, the sleek Tipo 125S roadster, was powered by a 1.5-liter V12, and started Ferrari's long record of racing victories. In 1950 the Formula One World Championship series began, and Ferrari soon won the first of 14 F1 championships to date. These victories and many more at Le Mans and elsewhere have added to the fervor of Ferrari fans (*Tifosi* in Italian). Famous Ferrari cars include the 250 GTO, the Testarossa, the Dino, the 550 Maranello, the F40, the F50, the F430, and the Enzo. Pininfarina and a few leading designers and coachbuilders have always created striking bodies for these cars, and Ferrari cars continue to offer an outstanding blend of technical and esthetic excellence.

1999 Ferrari 360 Modena

FORD

Henry Ford incorporated Ford Motor Company in 1903, and it rapidly grew to become a major force in the fledgling automobile industry. The Ford Model T, introduced in 1908, revolutionized the mass-production of affordable automobiles. Key to its huge production was Ford's pioneering use of the moving assembly line. In nineteen years Ford manufactured more than fifteen million Model Ts.

Ford entered the luxury market by purchasing the Lincoln Motor Company in 1922, and started the mid-priced Mercury brand in 1939. By 1927 the Model T was losing sales to more modern cars from other companies, so Ford replaced it with the more competitive Model A, and produced four million Model As in four years. In 1932, Ford Motor Company became the first auto manufacturer to offer an affordable V8-powered car. In the mid-1950s, Ford added the sporty Thunderbird to its lineup, and the 1960s saw the introduction of the best-selling Mustang. Ford introduced the exotic GT-40 in 1964, which won the Le Mans 24-hour road race four straight times in 1966–1969. In 2004, Ford began producing a new street version of the Ford GT, directly inspired by the GT-40 race car. At the other end of the spectrum, Ford entered the sport compact market with the affordable high-performance SVT Focus.

2003 Ford Focus SVT

HONDA

Starting in 1948, Soichiro Honda filled an important niche in post-WWII Japan by building motorized bicycles, but his Honda Motor Company soon grew to become one of the world's largest and most successful motorcycle manufacturers. This success allowed Honda to start building small cars in 1960. The energy crisis of the 1970s made Honda's efficient Civic, with its low-emission CVCC engine, a best-seller in many markets. The mid-size Honda Accord introduced in 1976 also added to the worldwide reputation of Honda. In the 1980s the company started building cars in the U.S. and Canada.

Soichiro Honda had always been interested in motorsports, and by 1961 his motorcycles were international winners. He sought the same success in automobile racing at the highest level—in Formula One and Indy Car racing. In 1964–1968, Honda campaigned its own cars in the Formula One World Championship, and since 1983 has supplied engines to other constructors. In 1988, Honda-powered F1 cars won fifteen of sixteen races. In 2006, Honda once again began running its own cars in the Formula One World Championship.

2003 Honda S2000

HYUNDAI

South Korean industrialist Chung Ju-Yung founded Hyundai Motor Company in 1967 as part of his Hyundai Group, a major engineering, construction, and shipbuilding enterprise. The company grew to become South Korea's major car manufacturer. Hyundai exported cars to Asia, Europe, and the Middle East in the 1970s and 1980s, and entered the U.S. market in 1986 with the subcompact Excel.

Hyundai soon established its reputation as a maker of affordable cars, starting with subcompact models for entry-level buyers, then added both sportier and more luxurious models to its lineup. Current Hyundai models include the Tuscani sport coupe (called the Tiburon in the U.S. market). Now the seventh-largest car maker in the world, Hyundai sells its vehicles in up to 193 countries across several continents, and has sold around 2.5 million units worldwide.

2003 Hyundai Tuscani Elisa

INFINITI

Japanese manufacturer Nissan Motor Company introduced its luxury Infiniti brand in 1989, focusing on a blend of style, comfort, and performance. The Infiniti flagship was the potent V8-powered Q45, which featured technology such as active suspension and four-wheel steering. Over the years the Infiniti line has grown to include the slightly smaller M45 sedan, the sporty G35 coupe (on the same chassis as the Nissan Skyline), and G35 sedan.

2003 Infiniti G35 Coupe

JAGUAR

British automobile maker Jaguar began in 1922 as the Swallow Sidecar Company, building stylish aluminum sidecars for motorcycles. By 1926 it was also producing custom bodies for other manufacturers' cars. In 1931 the company began building its own cars under the SS name (for Swallow Sidecars). Long, low, and sporty, the SS1 looked like a more expensive car than it was. In 1935 the company used the Jaguar name for the first time on a stunning new sports car, the SS Jaguar 100.

After WWII, the company became Jaguar Cars Ltd. The beautiful 120-mph XK120 sports car appeared in 1948. The racing version, called the C-type, won Le Mans in 1951 and 1953. In 1954, Jaguar introduced the more powerful XK140 sports car and the D-type racer, which won Le Mans in 1955, 1956, and 1957. The sensational 150-mph E-type sports car, introduced in 1961, was the most visually striking in a long line of attractive cars. Ford Motor Company acquired Jaguar in 1989, and has carefully preserved Jaguar's unique identity. Between 1992 and 1994 Jaguar produced 281 XJ220 supercars, and in 1995 launched the sleek, V8-powered XK-8 sports car. Most recently Jaguar unveiled its new supercharged sports car, the Jaguar XKR. Building on the excellence of the most technologically advanced Jaguar ever, the all-new XK with the 4.2 V8 engine introduced in late 2005, the XKR takes the Jaguar experience to new heights. For more than seventy years Jaguar has maintained its vision of the well-bred sporting automobile, combining superior performance with unique style.

1993 Jaguar XJ220

KOENIGSEGG

Christian von Koenigsegg founded his Swedish supercar company, Koenigsegg Automotive Ltd., in 1994. Its mission is to build exclusive two-seat, mid-engine super sports cars based on state of the art Formula One racing technology for a few select customers. Bodies and chassis are made of lightweight carbon fiber composite reinforced with Kevlar and aluminum honeycomb. These cars offer a combination of race car performance and superior comfort for long-distance touring.

After three years of development and testing, Koenigsegg showed its first production prototype at the Paris Motor Show in 2000, and delivered its first production car, the 655-hp V8-powered CC8S, in 2002. This luxurious 240-mph supercar features a custom leather interior and fitted luggage, along with a host of high-tech features seldom seen outside of advanced race cars. Koenigsegg introduced the 806-hp CCR in 2004, and the CCX, which delivers the same performance using 91-octane fuel and meets even more stringent emissions requirements, in 2006. Koenigsegg creates each car in its very limited production specifically for each customer. Like racing cars, these formidable vehicles can be set up to perform on any track or set of road conditions. Unlike racing cars, they are well-mannered on the street and offer a level of luxury no race car driver ever enjoyed.

2002 Koenigsegg CC8S

LAMBORGHINI

After WWII, Ferruccio Lamborghini started converting military vehicles into tractors, and began producing his own tractors in 1948. Many questioned his judgment when he decided to build sports cars to compete with Ferrari, but in 1963 he founded Automobili Ferrucio Lamborghini. The 350 GT was the first in a long line of striking designs to wear the charging bull badge, with Lamborghini's own V12 engine and chassis, and coachwork by Touring of Milan. In 1966, Lamborghini produced the first mid-engine supercar, the Miura, a barely tamed race car for the road, named for a legendary breed of Spanish fighting bulls. Its 4-liter V12 was mounted transversely behind the cockpit, and its sensational body by Bertone blended aggressiveness and elegance.

In 1974, Lamborghini introduced the Countach, an angular mid-engine supercar that never lost its ability to astonish first-time viewers and drivers. Its successor had to be extreme and spectacular; the Diablo was all that and more, with exotic styling, a 5.7-liter V12, and all-wheel drive. In 1998, Audi AG acquired Lamborghini, and in 2001 replaced the Diablo with the Murciélago. Aptly named for a famous fighting bull, it combines modern sophistication and brute force, with a potent 6.2-liter V12 (enlarged to 6.5 liters in the 2006 Murciélago LP640) and all-wheel drive. In 2003, Lamborghini introduced the Gallardo, a high-performance sports car designed for everyday use, with all-wheel drive and a 500-hp V10. Ferruccio Lamborghini's goal to build cars that compete with the world's best has been fully realized.

2005 Lamborghini Murciélago

LANCIA

Vincenzo Lancia began building cars in 1906, and this Italian car manufacturer (part of the Fiat Group since 1969) quickly developed a reputation for technical innovation. Its first car, the 1907 Alpha, featured a tubular front axle. The 1913 Theta included the first built-in electrical system in a European car. The 1922 Lambda featured V4 power and independent suspension, and the 1933 Augusta was the first sedan with a load-bearing monocoque body. The 1936 Aprilia was one of the first mass-produced cars with a truly aerodynamic shape. The 1950 Aurelia was powered by the first V6, and mounted its clutch, gearbox, and differential in a single unit on the rear axle.

Over the years, Lancia cars made their mark in road racing and at times dominated rally competition. Winning Lancias included the D50 Formula One racer that appeared in 1954. When the Lancia family sold its interest in the company, Ferrari took over the Lancia team. The renamed Lancia/Ferrari D50 won the F1 world championship in 1955. Some of Lancia's greatest competition successes came from rally cars. The futuristic, wedge-shaped Lancia Stratos won the World Rally Championship three straight times in 1974–1976. Even more successful was the HF Integrale version of the Lancia Delta and its ultimate development, the Evoluzione. This powerful four-wheel-drive hatchback won six consecutive Constructors Championships between 1987 and 1992.

1974 Lancia Stratos HF Stradale

LEXUS

In 1989, Toyota Motor Corporation of Japan introduced its Lexus line of luxury cars to the U.S. market, and then Great Britain, Canada, and Australia a year later. The V8-powered LS 400 and the mid-size ES 250 set the tone for the new brand with excellent build quality, value, and performance. Lexus has fleshed out the line with sport coupe and sport utility models. Lexus cars have enjoyed major success in North America, and were offered for sale in Japan for the first time in 2005. Lexus successfully entered the world of sports car and endurance racing in 2004 with its Daytona Prototype, powered by a competition version of the company's V8. Current models include the IS300 and IS350 compact sports sedans and the V8-powered SC430 hardtop sports convertible.

2006 Lexus IS350

LOTUS

Compared to some other British car manufacturers, Lotus is a relative newcomer, founded by Colin Chapman in 1952. But Lotus has packed the stuff of legend into its 55 years, including a long string of celebrated sports cars and seven Formula One Championships. Chapman's innovative designs emphasized simplicity and lightness. In 1957, Chapman introduced two cars that exemplified this approach: the elegant Lotus Elite sports coupe and the Lotus 7, a minimalist high-performance roadster. The 7 remains in production after almost fifty years, built by Lotus until 1973, and then by Caterham Cars, which bought the manufacturing rights.

Lotus won its first Formula One victory in 1960 and its first World Championship in 1963. By 1978, Lotus had won five more World Championships and continued to innovate, experimenting with turbine power, four-wheel drive, lightweight composites, and the use of ground effects to generate downforce. The Lotus Esprit sports car, produced from 1976 to 2004, turned heads from the start, particularly when it appeared in a James Bond movie as a car with submarine capabilities. After Chapman died in 1982, the company changed hands. Under GM ownership from 1986 to 1993, Lotus turned the modest Vauxhall Carlton sedan into a 176-mph "super saloon." Current models include the Elise roadster and the Exige coupe. These diminutive fiberglass-bodied sports cars on aluminum frames maintain Lotus' fifty-year reputation for putting big performance into small packages.

2005 Lotus Elise 111S

MASERATI

Officine Alfieri Maserati was founded in December, 1914, in Bologna, Italy. Since then, Maserati has played a consistently important role in the history of sports car culture and its development. In 1926, Alfieri Maserati and his brothers built their first complete car, the Tipo 26, and Maserati himself drove it to a class win in its first race. Before and after WWII, legendary racing drivers such as Tazio Nuvolari and Juan Manual Fangio drove Maserati single-seaters to European victories. In the U.S., Wilbur Shaw scored back-to-back wins at Indianapolis in 1939–1940 driving a Maserati 8CTF. In the early 1950s, the A6GCS sports car proved itself to be a winner, and in 1957 the great Fangio won his fifth and final Formula One championship in the Maserati 250F. Maserati then began building competition cars for private entrants, including the race-winning Tipo 61, popularly dubbed the "Birdcage" Maserati because of its complex tubular frame.

In the late 1950s, Maserati focused on building cars in larger numbers, starting with the handsome aluminum-bodied 3500 GT. In the 1970s, Maserati produced a series of mid-engine GT cars, including the Bora, Merak, Khamsin, and Mistral, all named for desert winds. In 1993, Maserati was acquired by the Fiat Group. With the technical collaboration of Ferrari, the company now makes fast and elegant tourers including the Quattroporte sedan, and the Coupé and Gran Sport (Coupé and Spyder) GT cars. Maserati has returned to racing with the MC12 supercar, and remains one of the great Italian makers of sports and luxury cars.

2004 Maserati MC12

The Toyo Kogyo Co. of Hiroshima, Japan, the predecessor of Mazda Motor Corporation, built its first vehicle, the Mazda-Go three-wheeled truck, in 1931. All of the company's trucks were given the Mazda name, partly in reference to Ahura-Mazda, the Zoroastrian god of light, and partly because it sounded like the name of company founder, Jujiro Matsuda. The first Mazda passenger car, the R360 coupe, appeared in 1960. In 1961, Mazda started technical cooperation with the NSU of Germany for rights to develop and use the powerful, lightweight rotary combustion engine originally designed by Dr. Felix Wankel.

Mazda started selling rotary-engined cars in Japan in 1967, the same year it began exporting cars to Europe. Mazda entered the U.S. market in 1970 with the rotary-powered RX-2, and introduced the slightly larger RX-3 in 1971. Their ability to leave cars powered by larger conventional engines behind made a big impression. Mazda introduced the RX-7 sports car powered by a twin-rotor Wankel engine in 1978, and its combination of power and handling made it an instant hit. The Mazda 787B prototype, powered by a four-rotor, 700-hp engine, won at Le Mans in 1991. Current models include an updated version of MX-5/Miata sports car, the Axela/Mazda 3 and Atenza/Mazda 6, and the latest Mazda rotary-powered sports car, the RX-8.

1997 Mazda RX7

Since 1990, McLaren Automotive in England has designed and produced a limited number of exclusive, high-performance road cars. Along with Formula One constructor and competitor Team McLaren Mercedes, the company is part of the McLaren Group. The organization is named after the late Bruce McLaren, a New Zealand-born racing driver, engineer, and race car designer whose creations won races in series from Formula One to CanAm. The McLaren F1 is a 240-mph supercar that uses technology from Formula One racing, including a strong, lightweight carbon fiber monocoque structure. Between 1992 and 1998, McLaren built one hundred F1s, priced in excess of US$1 million each. The F1's 6-liter, 627-hp BMW V12 gives this exotic three-seat coupe tremendous speed and acceleration, and the chassis provides handling to match. In 1995, F1s took first, third, fourth, and fifth places at Le Mans 24 Hours, proving that a million dollars also buys impressive durability, along with racing capability.

In 1999, McLaren started working with DaimlerChrysler to develop and build the Mercedes-Benz SLR McLaren, which debuted in 2003. For a lucky few with US$450,000 to spend, the new SLR provides unsurpassed levels of speed, handling, safety, and comfort. Like the McLaren F1, the SLR wraps a very powerful engine and a luxury interior in a lightweight composite structure. Its 5.4-liter, 617-hp AMG V8 propels the SLR to over 200 mph.

1997 McLaren F1 GT

MERCEDES-BENZ

Mercedes-Benz history reaches back to the dawn of the automotive era. In Germany, Karl Benz and Gottlieb Daimler were working independently to perfect the internal combustion engine and use it to propel a vehicle. In 1885, Benz became the first to build and patent a gas-powered vehicle, the three-wheeled Tri-Car. By 1900, both Benz and Daimler were selling cars in significant quantities. Daimler distributor Emil Jellinek named a new model for his daughter, Mercedes. In 1902 the low-slung Mercedes Simplex set a standard of performance with its 43-mph top speed. By 1911 the *Blitzen* (Lightning) Benz racer set a speed record of 141 mph.

In 1926 the two companies merged to form Daimler-Benz, making cars under the Mercedes-Benz name. Technical Director Ferdinand Porsche developed two of Mercedes' greatest cars, the supercharged SS and SSK in 1928–1931. Before WWII, Mercedes became a dominant force in Grand Prix racing with a series of technologically advanced machines. From 1952 to 1955, Mercedes returned to racing with the Le Mans-winning 300 SL and the W196 Formula One car, which proved equally dominant. In 1989, Mercedes started supplying engines to race car constructors Sauber and McLaren. The company partnered with McLaren to launch the 200-mph Mercedes-Benz SLR McLaren supercar in 2004. From the spindly, bicycle-based Tri car to today's SLR supercar, the history of Mercedes-Benz is the history of the car itself.

2005 Mercedes-Benz SLR

MINI

One of the most popular cars in recent years is the new MINI, launched by BMW's MINI subsidiary in 2001. This small, nimble car is a modern interpretation of the Morris Mini Minor, an even smaller car launched by British Motor Corporation in 1959 and produced until 2000. The original Mini was a revolutionary transverse-engine, front-wheel drive design that devoted 80% of its petite frame to passengers. It sipped gasoline, and handled surprisingly well, riding on tiny ten-inch wheels. Race car builder John Cooper designed higher-performance models called the Mini Cooper and Mini Cooper S. During its forty-year production more than five million Minis were sold, and the original remains a cult classic and tuner favorite.

In 1994, BMW bought the Rover Group, whose assets included the Mini, from British Aerospace. BMW kept the little car in production while planning its successor. The new MINI is available in three models: the basic MINI One powered by a 90-hp, 4-cylinder engine, the 115-hp MINI Cooper, and the supercharged 170-hp MINI Cooper-S. An optional John Cooper Works tuning kit increases horsepower to 210. In 2004 a soft-top MINI Cabriolet was added to the line. The new MINI may be a lot bigger than the original version, but is its spiritual successor, offering a lot of fun in what is for today a very small package.

2003 MINI Cooper S

MITSUBISHI

Mitsubishi Motors Corporation of Japan is part of the Mitsubishi Group, which began as a shipping and shipbuilding business in the 1870s. Mitsubishi built its first car—and Japan's first mass-produced automobile—in 1917. During the post-WWII fuel shortage, Mitsubishi built buses that could run on alternative fuels or electricity, and resumed passenger vehicle production in a small way with a motor scooter. By the 1960s, car production was back in full swing, from motorcycle-engined microcars to the Colt compact and mid-size Galant.

During the 1970s, Mitsubishi started a long string of international rallying successes with the Lancer compact. Over the years this model evolved into a formidable competitor, especially in the Lancer Evolution series, which won the World Rally Championship four consecutive times in 1996–1999. Since then these turbocharged, all-wheel-drive sports cars have grown in power and performance. The 2006 Lancer Evolution IX MR is a 2-liter, 286-hp version with a top speed of 165 mph. In the 1990s, Mitsubishi also produced two V6-powered performers, the 2-liter FTO and the 3-liter all-wheel-drive GTO.

2004 Mitsubishi Sparco Lancer Evolution VIII

NISSAN

Nissan Motor Company, founded as the Kwaishinsha Motorcar Works, produced its first car, the DAT (an acronym for the names of the company's three principal partners), in 1914. During the 1920s the company was reorganized as the DAT Automobile Manufacturing Company, and its new car was called the "DATSON"—son of DAT. Respelled as Dats*u*n, the name was used on the company's cars until 1983. After a 1933 merger with car manufacturer Nihon Sangyo (popularly called "Ni-San"), the company changed its name again to become Nissan Motor Company, and is now one of Japan's biggest and most successful car companies.

In the late 1960s, Nissan developed potent overhead cam 4- and 6-cylinder engines, and used them to power two extremely successful new cars: the Datsun Bluebird/510 sedan and the Fairlady/240Z sports car. These cars included features found on far more expensive competitors, such as front disc brakes and independent suspensions, and gained Nissan worldwide recognition for their low cost and high performance. In 1969, Nissan introduced the potent Skyline GT-R all-wheel-drive sports sedan and coupe, powered by the very successful RB-series inline 6-cylinder engine. The Skyline has been refined over the years. It now shares a chassis with the new Fairlady/350Z sports car, and is marketed in North America as the Infiniti G35.

2003 Nissan Fairlady Z

OPEL

Starting in 1863, Adam Opel manufactured sewing machines, and then bicycles, in Germany. The first Opel car appeared in 1899. In 1909, Opel launched the "Doktorwagen," a reliable and affordable car intended for doctors. Opel built its first race car in 1913, featuring an advanced overhead cam, 4-cylinder, 16-valve engine. In 1929, Opel became a wholly owned subsidiary of the American General Motors Corporation. Since then its cars have been sold in world markets under various names, including Opel, Vauxhall, Holden, Chevrolet, Pontiac, Cadillac, and Saturn.

Over the years Opel has produced many sporting and performance-oriented cars, and has had significant success in both rallying and touring car competition. The Opel GT two-seat sports car produced from 1968 to 1973 looked like a miniature Corvette and still has an enthusiastic following. In 1996, Opel established a subsidiary, the Opel Performance Center (OPC), to handle all of its European motorsport activities. OPC also develops high-performance versions of current Opel models, including the Astra, Corsa, and Zafira. From 2001 to 2005 Opel sold the Opel Speedster, designed and built by Lotus Engineering. Similar to the Lotus Elise, the Speedster provides strong acceleration and excellent handling. In 2006, Opel announced a new version of the Opel GT, a 260-hp sports car that shares its chassis with the Saturn Sky Redline and the Pontiac Solstice in North America.

2004 Opel Speedster Turbo

PAGANI

Argentine-born Horacio Pagani got involved with racing and race car design in his twenties, eventually securing a job with Lamborghini. He rose to head Lamborghini's composite materials department, and worked with the design team on several new models. Since 1999, Pagani Automobili of Italy has hand-built a few dozen coupe and roadster variants of its Zonda supercar, named for a warm, dry wind that blows across the Andes. Powered by a large-displacement Mercedes-Benz/AMG V12, this mid-engined, carbon fiber exotic provides acceleration, speed, and handling to match most cars in its rarified class.

For around US$320,000 the original 6-liter Zonda C12 surrounded its lucky owner in a luxurious custom cockpit while rapidly accelerating to 185 mph. The C12-S added a liter of displacement, US$30,000 in price, and an additional 35 mph top speed. Introduced in 2004, the Zonda GR is a lighter and even more aerodynamic competition version of the C12-S. Its 7.3-liter V12 accelerates the GR from 0 to 60 mph in 3.3 seconds. The Zonda combines the highest performance with wild good looks, luxury, and owner customization to make each of the few built a unique automobile.

1999 Pagani Zonda C12

PANOZ

Founded in 1989, Panoz Auto Development of Braselton, Georgia is part of the Panoz Motor Sports Group, which owns several professional racing series and tracks, and manufactures chassis for professional open-wheel racing. Since 2000, Panoz has produced coupe and roadster versions of the Esperante, an American interpretation of the European Grand Touring car powered by a potent four-cam Ford SVT V8. The Esperante is hand-built in small numbers, and Panoz tailors each car to the customer's taste. This upscale sports car is built almost entirely of aluminum, and features hand-sewn custom leather interiors. It provides a combination of handling and acceleration, finesse and muscle. The Esperante is offered in several models using variants of the Ford V8 rated from 305 to 420 hp.

As part of a racing-focused enterprise, Panoz cars have also proven themselves on race tracks. From 1999 to 2002, Panoz built an all-out race car, the LMP01 Le Mans Prototype, and raced it with considerable success in the American Le Mans Series (ALMS). In 2003, Panoz introduced the GTLM version of the Esperante, which adds a number of racing-inspired enhancements, including the 420-hp V8, more aggressive suspension geometry, reduced weight, increased structural stiffness and downforce, and higher-performance brakes and tires. All-out racing versions of the GTLM compete in the ALMS GT2 class.

2005 Panoz Esperante GTLM

PEUGEOT

French manufacturer Armand Peugeot produced a steam-powered, three-wheeled car in 1889. Early Peugeots took second place in the 1894 Paris-to-Rouen endurance run and won the 1895 Paris-to-Bordeaux race. During the next twenty years Peugeot became a major innovator, designing small, efficient cars including the "Bébé Peugeot," one of the first "mini" automobiles. Even more significant was Peugeot's development of powerful small-displacement engines that turned some Peugeots into giant-killers.

The Peugeots that won at Indianapolis in 1913, 1916, and 1919 was powered by a revolutionary 4-cylinder DOHC engine with four valves per cylinder. In an era when many racing cars were powered by monstrous slow-turning engines displacing 10 liters or more, this new 3-liter engine was a revelation, and influenced the Miller and Offenhauser engines that dominated Indianapolis for decades. In recent times the Peugeot 905 Le Mans Prototype won Le Mans in 1992 and 1993, and Peugeot built an impressive string of rally victories with a new generation of giant-killers. The 205 T16 Group B rally car won the World Rally Championship in 1985. A special AWD version of the Peugeot 206 won two World Rally driver championships and three successive Manufacturer championships in 2000–2002. Many future rally stars have driven Peugeot 106s and 206s to their first victories. Peugeot is one of a few car makers that can boast racing victories in three different centuries.

2004 Peugeot 206 RC

PLYMOUTH

From 1928 until 2001, Plymouth was Chrysler Corporation's low-priced car line, competing with Ford and Chevrolet. Simple, solid, reliable, and inexpensive, Plymouths soon became the third-best-selling American car, and sales continued to increase even during the Depression. In 1964 the Plymouth Barracuda became the first "pony car," beating the Ford Mustang to market by two weeks.

Originally the Barracuda was an upgraded version of the Plymouth Valiant, powered by Chrysler's 225-inch Slant Six, but before long it evolved to offer serious muscle in a relatively small and inexpensive package. The Barracuda Formula S, introduced in 1965, increased power with the small-block 273-inch V8, and in 1967 the Barracuda was revised to accommodate the big-block 383-inch V8. Special racing versions of the Barracuda even shoehorned the mammoth 440-inch V8 into the Barracuda, fed through three two-barrel carburetors in the "6-pack" model. In the early 1970s, Plymouth also made the legendary 426-inch Hemi V8 a Barracuda option. All of this muscle came at a price, and the Barracuda was discontinued a year after the 1973 oil crisis. In the 1960s and 1970s, Plymouth increasingly had to compete with other Chrysler products as Dodge introduced similar low-cost models. The brand continued in production, but after the formation of DaimlerChrysler in 1998, Plymouth fell victim to consolidation of the parent company's U.S. lineup, and ceased production in 2001.

1968 Plymouth Barracuda Formula-S

PONTIAC

For fifty years the Pontiac® division of General Motors has emphasized performance, but its history goes back twice that far. Edward Murphy founded the Oakland Motor Car Company in Pontiac, Michigan in 1907. In 1909, Oakland became a division of General Motors Corporation. In 1926, Oakland introduced the affordable Pontiac "Chief of Sixes," which outsold other models in the line. In 1932, GM created the Pontiac division, and dropped the Oakland brand. For twenty years Pontiacs filled a niche between Chevrolet and Oldsmobile in the GM lineup, but during the 1950s and 1960s the brand featured sporty models that offered higher performance.

The Bonneville, introduced in 1957, started as a large, high-performance convertible. In 1964, Pontiac started the "muscle car" trend with the GTO. This potent intermediate-size car took its name from the Ferrari GTO, but the Pontiac version was a quintessentially American recipe for performance: a big V8 driving the rear wheels of a relatively small and affordable car. The GTO was a huge hit until the oil crisis of 1973. In 2004, Pontiac reintroduced the GTO, now a modern, sophisticated interpretation of the 1960s muscle car based GM Australia's Holden Monaro. The latest Pontiac to emphasize handling and performance is the Solstice sports roadster, introduced in 2005.

2004 Pontiac GTO

PORSCHE

This German car manufacturer has produced some of the world's most successful sports and racing cars. Founder Ferdinand Porsche's earlier projects ranged from the mighty 16-cylinder Auto Union Grand Prix car to the humble Volkswagen. In 1948 his son introduced the Volkswagen-powered Type 356 sports car. The nimble 356 soon earned Porsche cars a reputation as giant-killers, beating brute force with finesse. Powered by a sophisticated twin-cam engine, Porsche's first purpose-built racer, the 550 Spyder, won its class at Le Mans in 1954 and overall victory in the 1956 Targa Florio.

Porsche continually developed the 356 until 1965 while maintaining its distinctive, curvaceous shape. The same pattern of long-range development continued with the 6-cylinder 911, which has been in production since 1964. The 911 has continually evolved, gaining power, performance, and new technology. Even with a switch from the air-cooled flat-six to a water-cooled version in 1997, the 911 has never looked like anything but its iconic self. The Boxster and Cayman mid-engine roadster and coupe share many design features with the 911. Porsche has also produced a long string of race and rally victories, including 16 overall victories at Le Mans. Race-winning Porsches include the 550 Spyder, the 904, the Le Mans-dominating 917, 956, and 962, the 911-based GT1, and the new RS Spyder. Few manufacturers can match the combination of name recognition and racing success Porsche has achieved.

2004 Porsche 911 GT3 (996)

PROTO MOTORS

Founded in 1997, Proto Motors is a small South Korean manufacturer that produces what it calls the country's first supercar, the Spirra. This small mid-engine sports car features an aluminum space frame, carbon fiber body, and gull-wing doors. It comes in two models, powered by a 2.5-liter DOHC supercharged 4-cylinder engine or a Ford 4.6-liter DOHC V8.

2006 Proto Spirra

RENAULT

Louis Renault built his first car in 1897. It featured a major innovation that became the basis of Renault's fortune, the first direct-drive gearbox. Renault believed that demonstrating his car's performance would increase sales. On Christmas Eve 1898 he bet that he could drive his machine up the steep grade of the Rue Lepic in Montmartre; he won the bet and landed twelve orders. If a solo climb up a steep Paris street could get his business started, racing victories would ensure its future. By 1902, Renault cars had won several city-to-city races, and Renault became a major manufacturer.

From 1946 to 1961, Renault manufactured the diminutive rear-engined 4CV, and racing versions took many class wins. Another small car that made a big hit was the Renault 5, produced from 1972 to 1984. With 180 to 350 hp, the mid-engine R5 Turbo rally version was an impressive performer. Renault has become a major force in rallying, road racing, and Formula One, introducing turbocharged F1 engines in 1977, and building normally aspirated engines for the Williams F1 team in the 1990s. In 2000, Renault bought the Benetton F1 team, renamed Team Renault in 2002, and won its first F1 championship in 2005. One of the most successful current Renault models is the Clio. Renault Sport has produced performance variants, especially the outrageous 150-mph Sport Clio V6, a mid-engine, rear-wheel-drive version with a Renault 3-liter V6 behind the front seats.

2003 Renault Clio V6 RS

SAAB

Swedish car maker Saab started out as aircraft manufacturer Svenska Aeroplan Aktiebolaget in 1937. The company produced its first car in 1949. The original Saab model 92 was small, lightweight, and, of course, aerodynamic, powered by a 25-hp 2-cylinder, two-stroke engine. The model 93, launched in 1955, added a third cylinder (for a total displacement of 748 cc) and eight horsepower. The Saab 96, produced from 1960 to 1980, featured a four-stroke V4 engine. In 1977, Saab unveiled the 99 Turbo at the Frankfurt Motor Show, a milestone in its history. The 99 Turbo established Saab as a manufacturer of exclusive cars with sporty characteristics. It was the first car to integrate high-performance turbo technology in a family saloon, a new approach that was expressed prominently in its legendary design features. Early Saabs excelled in rally competition, and compiled an impressive record until Saab withdrew from the sport in 1980.

In 1990, GM acquired Saab's automobile division and renamed it Saab Automobile AB. In recent years Saab has introduced a new model range, consisting of the flagship 9-5 and the mid-size 9-3. In 2006, Saab celebrated twenty years of building their iconic convertible models, currently represented by the 9-3 convertible, and also introduced the Saab Aero X concept car. This unusual two-seater sports coupe, influenced by Scandinavian and aircraft design, features a glass cockpit canopy that opens for passenger entry. This canopy offers full 180-degree vision and makes both doors and pillars obsolete. The Aero X is powered by a BioPower-Twin Turbo engine delivering 400 hp in an environmentally friendly way, using 100% bioethanol (E100) for fuel.

2002 Saab 9-3 Aero

SALEEN

Steve Saleen founded Saleen Performance Incorporated in 1984, the year his company produced the first of more than 8,000 Mustang-based performance cars with enhanced aerodynamics, power, and handling. The S281 is the latest version of the Saleen Mustang, offered in several configurations and performance variants, including the Saleen/Parnelli Jones Limited Edition Mustang introduced in 2006. This manufacturer of limited edition, high-performance vehicles now produces a range of cars, from the Mustang-based S281 and the S331 Sport Truck to the S7 supercar, unveiled in 2000. Saleen also produces performance parts, including wheels, exhaust systems, and brakes. In 1995, Saleen joined with actor Tim Allen to form the very successful Saleen/Allen "RRR" Speedlab racing team.

The S7, Saleen's first completely original design, is available as an all-out race car, but since 2001 Saleen has offered a more luxurious roadgoing version. Whether intended for road or track, the S7 is a true American-made exotic, attaching carbon-fiber bodywork to a hybrid chassis that combines aluminum honeycomb panels with a steel spaceframe. The normally aspirated S7 is powered by a 7-liter, 550-hp V8. Saleen has established such a significant relationship with Ford Motor Company that Ford contracted with Saleen in 2003 to perform assembly and paint work on its own supercar, the Ford GT.

2004 Saleen S7

SATURN

Saturn, the newest division of General Motors Corporation, was founded in 1985 and started producing cars in 1990. Unlike other GM divisions, Saturn initially concentrated on small, efficient cars to provide stronger domestic competition against Japanese imports. Since 2000, Saturn has diversified its line with the L-series midsize car, built on the same platform and using the same engine as GM's Opel Vectra, and the Honda-powered VUE sport utility vehicle.

The Saturn ION compact debuted in 2003 with sedan and "quad coupe" models, the latter featuring a pair of small rearward-opening doors behind the front doors for easier passenger access. In 2004, Saturn introduced a performance-oriented version, the supercharged ION Red Line. In 2006, Saturn announced another Red Line model, the two-seat, turbocharged 260-hp Sky Red Line sports car.

2006 Saturn ION Red Line

SCION

Toyota launched its youth-oriented Scion division for the U.S. market in 2003. These entry-level cars include the xA hatchback and the boxy xB wagon, both driven by a 1.5-liter, 108-hp four, and the compact tC "touring coupe," powered by a 2.4-liter, 160-hp four. Optional supercharging increases the tC's horsepower to 200. Scion models are available in one standard level of trim, but buyers can customize their Scion with an array of accessories, from decals and canvas tops to superchargers and subwoofers.

2005 Scion tC

SEAT

SEAT is a Spanish car manufacturer owned by the German Volkswagen Group. The company develops and produces vehicles that emphasize design, vitality, and sporty character—values that reflect the brand claim "SEAT auto emoción." The avant-garde, innovative spirit of the company is reflected in its seven models: the Alhambra, Altea, Altea XL, Córdoba, Ibiza, León, and Toledo. The international character of the brand is amply demonstrated by the fact that it distributes its vehicles in seventy-two countries, and exports two-thirds of its production.

SEAT entered international motoring competition to promote its cars on the most demanding international testing ground. SEAT became active in rallying in the 1990s, and the SEAT Ibiza won three consecutive World Rally Championships in 1996–1998. In 2006, SEAT was runner-up in the FIA World Touring Car Championship (WTCC) constructor's category. SEAT also achieved success in the fifth SEAT León Supercup when it introduced the sporty new León Supercup model at this prestigious road car event.

2005 SEAT Cupra GT Prototype

SHELBY

Carroll Shelby is associated with some of America's most iconic and most valuable high-performance cars. Shelby started racing in the early 1950s, and soon earned drives in Aston Martins (which he co-drove to win Le Mans in 1959), Ferraris, and Maseratis. In the 1960s he focused on building sports cars that could beat the world's best. In 1962 he re-engined the lightweight British AC Ace sports car with a small-block Ford V8. The result was the Cobra, a car that weighed nearly a ton less than the Chevrolet Corvette and offered stunning performance. Cobras were soon winning races, and Shelby set his sights on Le Mans. His Daytona Coupe, a hardtop Cobra with improved aerodynamics, won in its class at Le Mans in 1964 and 1965. In 1965, Shelby unveiled the 427 Cobra, powered by a 7-liter Ford V8.

Shelby was involved in the design of the Ford GT40 that dominated Le Mans in 1966–1969, and recently helped design the Ford GT, a street version of the original race car. From 1965 to 1970, Shelby produced two versions of his Shelby Mustang: the small-block GT350 and the big-block GT500. In the 1980s and 1990s, Shelby helped develop performance models for Dodge, and provided input on the design of the Dodge Viper. In 1998, Shelby produced the Series 1 roadster with a carbon-fiber body over an aluminum honeycomb frame, powered by an Oldsmobile Aurora V8. Shelby's long career forms a unique chapter in the history of American cars.

1999 Shelby Series 1

SUBARU

Subaru is a Japanese car company, the automotive division of Fuji Heavy Industries Ltd. (FHI). FHI was established in 1953 and started to develop a car using aerospace technologies developed by aircraft manufacturer Nakajima Aircraft Ltd., which was the predecessor of FHI. In 1958, FHI introduced its first car, the Subaru 360, adopting the car's name and its symbol, the six-star cluster, representing the Pleiades star cluster. In 1965, Subaru introduced the front-wheel-drive Subaru 1000 at the Tokyo Motor Show, featuring a 4-cylinder horizontally opposed boxer engine.

In 1972, Subaru took a bold step by introducing the first four-wheel-drive (4WD) vehicle designed specifically for everyday driving, the Leone 4WD Station Wagon. Until then, 4WD had been limited to off-road and specialty vehicles, giving the Leone 4WD the distinction of introducing the safety and performance advantages of 4WD to a whole new segment of drivers around the world. In 1989 the Subaru Legacy, which boasts both a horizontally opposed boxer engine and the latest in Subaru all-wheel drive (AWD), was launched, and by 2005 Subaru had sold three million of them. In 1992, Subaru introduced the Subaru Impreza, which won three consecutive World Rally Championship titles in 1995–1997.

2005 Subaru Impreza WRX STI

TOYOTA

Early in the twentieth century Sakichi Toyoda invented a series of industrial looms. In 1933 he used some of the proceeds to establish an automotive division of his Automatic Loom company, which produced its first car in 1935. In 1937 the renamed Toyota Motor Company became an independent operation. Since then it has become the world's second-largest car maker, with facilities in twenty-seven countries. In the 1950s, Toyota entered other world markets. When the company started tailoring cars to these foreign markets, sales began to soar. Since 1966, Toyota has sold 30 million compact Corollas worldwide.

Between 1967 and 1970, Toyota produced about 350 copies of the sophisticated 2000GT sports car, a statement of the company's intention to build cars to compete with the world's best. In 1970 the Toyota Celica four-cylinder sports car appeared, and the six-cylinder Celica, later called the Supra, was introduced in 1978. The two cars became completely separate models in 1986, when the Celica switched to front-wheel-drive. The Supra remained in production until 2002. From 1984 to 2005 Toyota produced a small mid-engine sports car, the MR2 (renamed MR-S in Japan in 1999), which offered an affordable taste of the mid-engine performance. At the luxury end of Toyota's sports car spectrum is the Soarer, introduced in 1981. The current model is a V8-powered luxury roadster with a convertible hard top, sold in all markets as the Lexus SC 430.

1969 Toyota 2000GT

TVR

Trevor Wilkinson founded this British maker of hand-built sports cars in 1947. TVR has always emphasized light weight, high power, and overall simplicity, omitting driver aids like traction control and antilock brakes. Early models used small-displacement engines from other manufacturers, wrapped in a fiberglass body on a tubular steel chassis. The nimble TVR Grantura sports car, introduced in 1958, was originally designed for 4-cylinder engines up to 1.5 liters, but in 1962 American tuner Jack Griffith dropped a small-block Ford V8 into a Grantura's engine bay. TVR agreed to supply additional chassis, and the Grantura became the Griffith 200, a small beast of a car with up to 271 hp. TVR itself produced a V8 sports car, the Tuscan, from 1967 to 1970.

In recent years, TVR has built its own engines in-house. The 4.0-liter Speed Six powers two variants of the latest TVR Tuscan, launched in 2000. The Tuscan S street version uses a 380-hp version, and the Tuscan R, which can be configured as an all-out racer, boasts 450 hp and enhanced aerodynamics. In the late 1990s, TVR built and campaigned a GT1 race car powered by a 7.7-liter V12 consisting of two Speed Sixes mated to a common crankcase. In 2000, TVR built a prototype street version of this 2,200-lb, 800-hp racer, the Cerbera Speed 12, one of the fastest road cars ever built.

1998 TVR Cerbera Speed 12

VAUXHALL

Vauxhall produced its first car in 1903, and Vauxhall Motors Ltd has been a subsidiary of U.S.-based General Motors since 1925. Early Vauxhalls were both fast and durable. In 1909 a rebodied A-type Vauxhall became the first in its class to exceed 100 mph over a flying mile. The modern, low-slung 1911 C-type, or "Prince Henry" Vauxhall is often called the first production sports car. The pre-WWI E-type was among the world's fastest production cars with a top speed around 85 mph. Vauxhall remained a relatively low-production manufacturer until its acquisition by General Motors. In the 1930s the company's emphasis shifted to the production of less expensive cars in larger numbers, and their popularity helped make Vauxhall a major manufacturer.

In the 1960s, Vauxhall began building the Viva, a small car first produced by German GM subsidiary Opel, as the Kadett. The Astra hatchback, introduced in 1979, was also an Opel design. It is now sold worldwide as an Opel, Vauxhall, Holden, or Chevrolet. The hottest of all Astras is the 2-liter, 240-hp VXR. Its big brother is the Monaro VXR, based on the Monaro produced by Holden, GM's Australian subsidiary. Powered by the 403-hp V8 used in the Chevrolet Corvette, this high-powered flagship of the Vauxhall line has a 180-mph top speed.

2005 Vauxhall Monaro VXR

VOLKSWAGEN

Volkswagen, one of the world's major car makers, took its name from the humble "peoples' car" prototyped by Ferdinand Porsche in 1936. WWII intervened, and no production cars were built until late in 1945, under British supervision. This little aerodynamic rear-engined, air-cooled car, now universally known as the "Beetle," was soon embraced worldwide. The last German-built Beetle rolled off the assembly line in 1978, but this 1930s design remained in production in Mexico until 2003. Total production was just over 21.5 million.

Volkswagen introduced the Beetle's successor, the Golf, in 1974. This hatchback, with its liquid-cooled 4-cylinder engine and front-wheel drive, proved to be an even bigger hit, with 24 million sold by 2005. The GTi performance version of the Golf appeared in 1976, starting the "hot hatch" boom that continues to this day. The current version features a turbocharged 2-liter, 200-hp engine. The Jetta, a sedan version of the Golf, appeared in 1980; in Europe the current version is called the Bora. In 1988, Volkswagen introduced the sporty Corrado with excellent handling and optional V6 power that appealed to those who wanted a high-performance hatchback. Volkswagen's history came full circle in 1998 with the introduction of the New Beetle, a thoroughly modern interpretation of the original based on the Golf platform, with its front-mounted, liquid-cooled engine and front-wheel drive.

2004 Volkswagen Beetle

Volvo was founded in 1927 as part of the Swedish SKF Group, a manufacturer of ball and roller bearings. "Volvo" is Latin for "I roll," a name appropriate for both bearings and for cars. Volvo, which became an independent company in 1935, has established a worldwide reputation for safety innovations, from the three-point seatbelt to crumple zones, collapsible steering columns, and side impact airbags. The company's founders maintained from the outset that its operations should be based on safety, quality, and the environment as core values. The design of Volvo cars reflects their Scandinavian origins, with emphasis on both elegance and functionality. This design tradition includes elements that have been found in Volvos since the 1950s, such as the vertical front, the V-shaped bonnet, the pronounced shoulders along the sides of the car, and the shape of the tail lights. Over the years Volvo models have gained in performance and luxury, and have added safety features that are now world standards. An excellent example of Volvo's current combination of style, safety, and performance is the S60 R. Based on the S60 sedan, the S60 R (the R stands for "refined") offers superior power and handling. Featuring a 300-hp, 2.5-liter turbocharged inline 5-cylinder engine, upgraded wheels, tires, brakes, and a computer-controlled active suspension system, the S60 R is a highly refined competitor for many manufacturers' performance models.

2004 Volvo S60 R

An Interview with Art Director John Wendl

Art Director John Wendl is responsible for the visual world of *Forza Motorsport 2*. This interview takes you behind the scenes to understand how he and his team capture and digitize the cars, tracks, collisions and damage, trees and vegetation, skies, and spectators, re-creating the unique character and feel of the world of *Forza Motorsport*. For version two, the special challenge was to harness the increased graphical power of the Xbox 360 to enable better frame rates and the realistic play of light and shadow as players lap a track. John details how his team gathers data about the race tracks in the game to reproduce each one with increased fidelity. He also discusses some interesting trade-offs—when, for instance, is art called upon to temper reality? Finally, he talks about empowering gamers with tools that let them express their own creativity.

"We tried to empower users as much as possible and leave the creative part up to them. We tried to remove as many limitations and barriers as possible and give them a blank canvas so they can exploit the power we give them. … We were just blown away by the things our users were able to do … It's just going to get better in Forza Motorsport 2.*"*

Q: ***Describe the effort that went into making* Forza Motorsport 2 *the most realistic-looking racing game yet. Version one set a really high bar. What are you doing to raise the bar?***

We set a high bar for version one, but we were limited to some extent by the power of the original Xbox® console. Moving to the Xbox 360, we had an opportunity to improve on fidelity because of the increased power of the box. We looked at things like 720p resolution, 60 frames per second (fps), motion blur, and fullscreen anti-aliasing. One thing that motivated us was that increased power. The intro video we shot for the original *Forza Motorsport* was a cinematic based on in-game captures. So we rendered screens out at high resolution. They were from the game, but they were high res and we sampled them at higher rates so we could add motion blur and other effects. We looked at it and said, "Wow! That looks even better than the game, and we're going to get all this stuff with the Xbox 360 that we couldn't do in real time on the original Xbox."

That was really the first big jump that we identified, harnessing the power of the box to make the game look better. Then we wanted to reexamine things from the ground up and figure out what's holding us back from the next level of realism. We were looking at our scene from a fresh perspective and saying, okay, when we look at this, what looks most realistic, what are the things that still aren't quite there, what is giving us the most problems, what's holding us back from breaking through? How can we leverage more of the power of the Xbox 360? How can we change the way we gather reference material for some of these assets? How can we work effectively to try to get more realism and try to raise everything up? So we looked at everything. We reexamined the way we do tracks, surfaces, trees, cars, skies, lighting—*everything*, and really tried to pull it all together. We not only wanted to do everything to a high level of realism, but we also wanted things to be at a consistent level of realism, because a lot of times consistency is more important than how real things actually look.

Six or seven years ago there were a lot of wave race games coming out. There were cool algorithms for doing realistic water, and it looked great. But a lot of objects near the water didn't look so great, and it ended up making the game look really weird. It made the things beside the water look a lot worse because you were comparing it to the fidelity of the water. Sometimes if you have things that are very realistic next to things you can't get to that same level of fidelity, it ends up hurting you more than it helps. It's not that we scale things back, but we try to get everything to an even level. That was part of the goal of identifying key areas that needed work. We wanted to look at additional texture resolution. We put a lot of detail into the track surfaces in the first version of *Forza Motorsport*. We had the rubber grooves and braking marks and patches and stains and all that stuff, but really we were limited with the resolution in those textures. So we went back to the original photo source material we had taken and basically quadrupled all of our track textures so we could get all of the little nuances, like little cracks and oil stains and patches of rubber to use them as reference points the way drivers do. We wanted to achieve a higher level of fidelity. Another big area for us was grass and vegetation. They were flat polygons in the original game, and now we're looking at real 3-D grass, mown grass and long grass that has volume and texture and catches lighting. And there are a lot of trees around race tracks, and they have a big impact on the way tracks look. Now we have much better tree technology, including improved lighting for casting realistic shadows.

Our skies have a lot more resolution, and we're developing high-dynamic range lighting for our skies, and getting better lighting across the entire scene. We have much more tunability and controllability to immerse gamers in the experience.

Honestly, our crowds weren't all that great in version one. They supported the game, but they didn't really call attention to themselves. They were just flat people who followed you where you went. We've got full 3-D animated crowds this time that go through various animations around the track and add a lot of life to the environment.

We've made a lot of improvements to car rendering, including more damage. We're actually losing bumpers this time, so you see more of the undercarriage when you damage the car. We're trying to make damaging your car feel more dramatic, so you get the sense you've just hit something at speed.

We've made a lot of improvements in the way we do reflections and lighting on cars. For lighting operations, with the power of the Xbox 360 we can do per-pixel reflections and lighting, which gives us a much finer level of detail as these effects move across surfaces. When you're driving you spend a lot of time staring at your car. So now reflections are going to be moving just as smoothly as everything else. That's going to add a lot of gameplay immersion.

Q: Can you talk about how you capture miles of track accurately? Do you take a picture of every foot of it?

It's a pretty complicated process. It depends on the length of the track and the type of track. We have fictitious tracks, city tracks, and real-world road courses, and the process we go through for each of those is a little different. Our primary case is the real-world road courses, and all the new tracks in *Forza Motorsport 2* are real-world road courses, so I'll elaborate on that process. The good news is that the courses exist in reality, so it's just a matter of capturing the data. There's not a lot of design direction we can put on it, because we're trying to re-create the track and the ribbon layout as accurately as possible. We use a lot of different pieces of hardware. For version two of the game, we moved to a Global Positioning System (GPS) that is sub-foot accurate, a really high-end system that can measure not only longitudinally but also vertically, so we can get the elevation right. Most common GPS systems can get the horizontal stuff fairly accurately, but they're terrible at the vertical. This system is sub-foot accurate for the vertical and sub-inch accurate on the horizontal.

Basically we take the GPS system and drive it along the outer edge of the track and the inner edge of the track, and plot all the various details, so things are reproduced inch-perfect. There's no more lining up all the photos and videos and trying to guess lines of sight. Everything is perfect right off the bat, so we get our geometry perfect. We do several passes with a video camera so we understand the field of view and how everything lines up in the distance. We do passes to the left, straight ahead, to the right, and to the back, and we take thousands and thousands of still photographs, and detailed notes. We'll typically have a team of three or four people: one guy's doing the GPS, one is taking notes and measurements of bank angle and so on, and others are taking photographs and video of every inch of the track. Depending on the length of the track, about every tenth of a mile we shoot panoramic shots all around the track. We find a high point and shoot the sky and aerial shots looking down. We even rent aircraft and shoot from above straight down to get an idea of all the terrain and topology. There's a ton of effort and data that goes into making these things look as real as possible.

Q: Was all this part of the effort for the original Forza Motorsport?

Some of it was, but the GPS and aerial photography weren't. We did take a lot of still photographs, some video, and some measurements; but like everything else, we've gotten a lot better with our process and gone to the next level of accuracy. And honestly, at the resolution on the original Xbox, that accuracy might not have been missed, but now with the Xbox 360 the fidelity is so high that you have to get things to this level of accuracy. The curbing needs exactly the right detail. The patches on the edge of the track and all those things need to be inch-perfect now.

Q: You provide art direction, but at the same time you're re-creating reality. How do the two mesh? It's artistic and aesthetic, but at the same time it's everything around you—it's reality.

Right—but there's a famous quote in games: "Photo-realism is not a style." That's true. We do strive to create reality, but everyone's perception of that reality is a little bit different. The way the human eye sees light and color and the way the brain processes that, peoples' memory of what they see varies. We study film and all kinds of images to understand this. There are a lot of different ways that you can portray reality. What we're going for is a certain mood, a certain drama, and try to get variety across our tracks so people feel a certain way. One of the interesting things we saw recently was *Cars*, the movie, and we read a lot about what they were trying to achieve there. It's pretty interesting because they were not necessarily going for what the scene looked like, but what people remember about how it looks. Typically, you remember things a little bit differently. Colors may be a little more or less vibrant. It's how you remember the atmosphere, and we're trying to put all that together and evoke an emotional response.

In some cases we go for pure realism. In other areas we want to embellish the experience—we want this to be exciting. Sometimes race tracks aren't the most exciting things to look at. They're designed to be very safe, so things tend to be very far away. We're still accurate, but there are things we can do with visuals to help embellish the sense of speed and heighten drama, and all that heightens the player experience, to give people a framework to go in and have fun and feel excited. If you just give them "real"—like with our physics—if you give them completely real, it can be very frustrating. So we do some things to tune it and make it more accessible to players.

Q: *So you touch things up a little bit to look more gamelike?*

Sometimes to appear more gamelike, but sometimes just to appear the way we want to portray it. We might bend lighting to make it a more twilight situation, or we might embellish reflections on surfaces so they stand out more, or get more specular on trees, or do something with the sky or road textures to make them a little more visible. Some of this is related to gameplay because it's difficult to see the track surface, so we do some things to help you spot your braking markers or where the turn goes. But other parts are really just to help players feel the mood and the experience we're trying to portray visually.

Q: *Do you take subjective liberties with the car modeling?*

No, we really can't, and even on the track models we don't do anything subjective. It's more in the surfaces and the mood and the lighting. We can't change the shape of the cars or tracks.

Q: *So it's more about ambience.*

Exactly. The cars have to be inch-perfect; in fact, better than that. And all of the manufacturers have to sign off on the shape and surfaces of the cars. We just try to make them look as smooth and perfect and as realistic as possible. And then we try to tie in the lighting, the way the wheels blur, and so on. That's where some of the artistic expression comes in with cars. How the parts damage, how things look when they're moving, how particles, sparks, and smoke come off the car. How motion blur works, how reflections on the glass work, and so on.

Q: *In Forza Motorsport 2 the 300-plus cars look more detailed. How many hours does it take to build a car?*

To create a new car from scratch typically takes about two months. We have a lot of people working on cars. The Art team at our peak was over one hundred people. You have to build a core mesh from scratch. You have to paint the texture. We create levels of detail (LODs) so as the car goes off into the distance you don't have to spend as much computational power on it. We have to damage the car. We have to create custom parts for upgrading the car, which include LODs and damage. We have to set things up so the car can be painted in the Livery Editor. We have to address all the different surface properties and shader settings and tuning, little helper objects that place the driver, particle emitters, and so on. A ton of work goes into that. So a new car from scratch is about two months' work, and we spent five or six weeks on every version one car that's now in version two, adding another level of detail to it, making it that much better.

Q: How has the idea of custom liveries evolved, and perhaps surprised you?

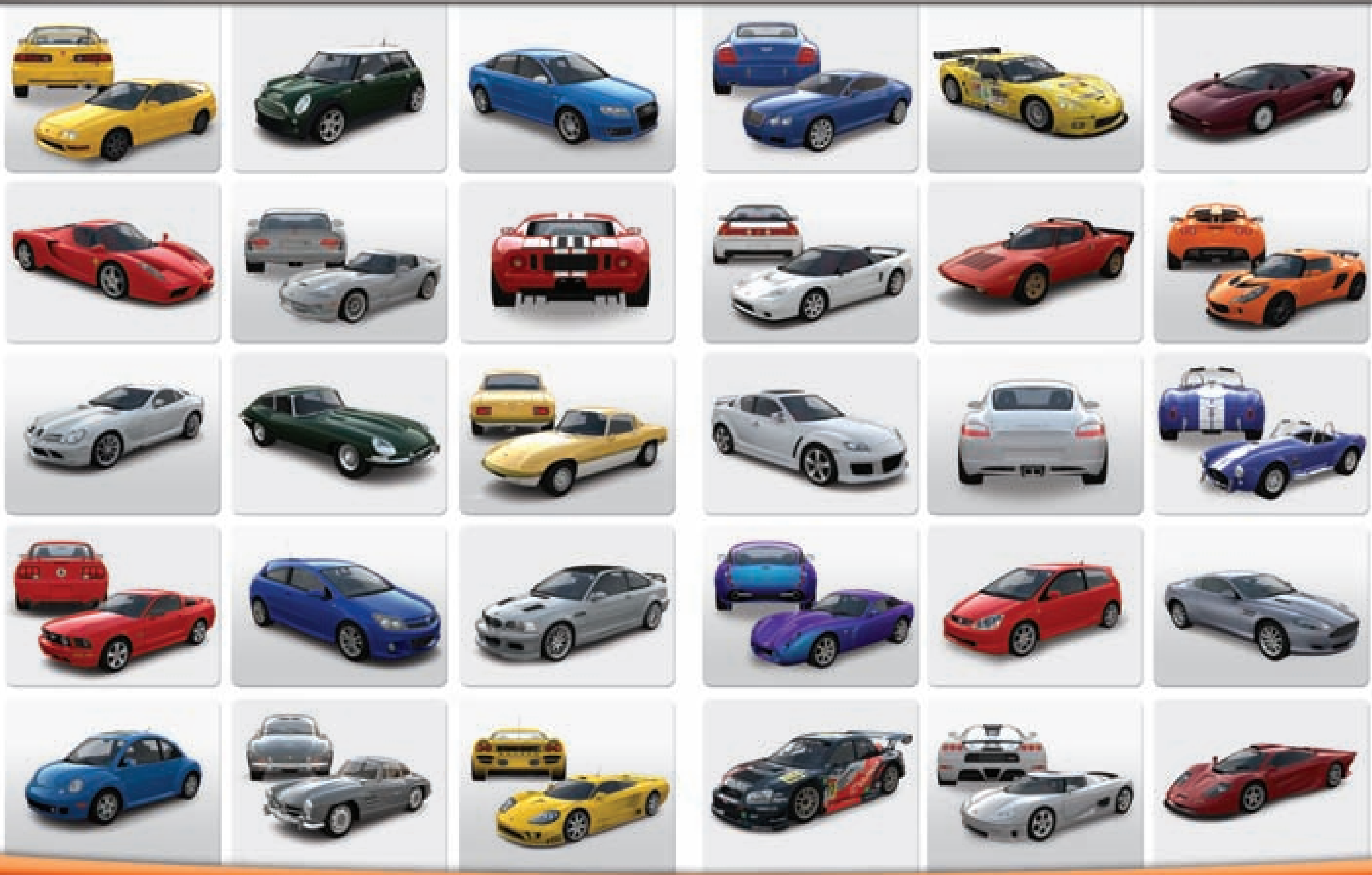
It's pretty cool. What we tried to do was what we do with any tool: we tried to empower users as much as possible and leave the creative part up to them. We tried to remove as many limitations and barriers as possible and give them a blank canvas so they can exploit the power we give them. We gave them a hundred layers to work with, and they can scale and size and color things in a lot of different ways. We were just blown away by the things our players were able to do, and we're blowing the roof off of it this time. Originally we thought that 100 layers would have to be enough, but we found people working hard to try to stay within that number of layers. So we're giving people the ability to create vinyl groups, create stamps, and share some things like logos. This is going to go a long way, and we're going to see even more crazy stuff this time.

Q: What's the coolest design you've seen from the Livery Editor where you couldn't believe what people made with the tools you gave them?

There were so many of them. There was the *Halo® 2* car, the car with the Sistine Chapel paint job and Michelangelo's David, the Darth Vader car, and many others. When I saw them for the first time, I thought "That's it—we've been hacked. Someone has figured out how to get a Photoshop texture into the game!" We went through it, and sure enough, they were legitimate. They had to go through the Livery Editor a bunch of times to figure out how to do it in 100 layers. They'd get to layer 99 and figure out that they needed five more layers. At that point you're kind of done; it's hard to go back and do much with that. But now, not only do you get additional layers, but you can composite and stamp things more easily. People will be running into fewer issues creating their own liveries.

I just couldn't believe the stuff people were able to come up with, even with the limitations we had in version one. It's just going to get better in *Forza Motorsport 2*, and that's true of the new version's graphic quality and detail in general.

A SAMPLING FROM THE STABLE



2004 HONDA CIVIC TYPE-R

This representative sampling from the *Forza Motorsport 2* stable provides a glimpse into the diverse collection from which you can choose. Our 300-plus cars are divided into six production classes and four race classes:

- **D** Standard production cars including the Ford Focus SVT and the Volkswagen Beetle
- **C** Sport production cars including the Audi S4 and the Nissan Fairlady Z
- **B** Performance production cars including the Porsche Cayman S and the Lotus Exige
- **A** High-performance production cars including the Chevrolet Corvette Z06 and the Ferrari 360 Modena
- **S** Ultrahigh-performance production cars like the Maserati MC12 and the Porsche Carrera GT
- **U** Unlimited-class cars including the Chrysler ME Four-Twelve concept car and the TVR Cerbera Speed 12

- **R4** Heavily modified production cars and purpose-built race cars including the Subaru GT300 Impreza and the Porsche 911 GT3 Cup
- **R3** High-end purpose-built race cars including the Dodge Viper GTS-R and the Nissan GT500 Skyline
- **R2** Ultrahigh-end purpose-built race cars including the McLaren F1 GTR and the Chevrolet Corvette C6.R
- **R1** Prototype race cars including the Porsche 962C and the Audi R8

This hot Honda hatchback benefits from Honda's Type-R treatment, including engine and suspension tuning. Its high-revving VTEC engine is also fast-revving due to a lighter flywheel, making for rapid acceleration. Its body is braced for additional stiffness. Its lowered suspension includes stiffer springs, dampers, and anti-roll bars to improve handling, while spoilers and side body panels make a significant aerodynamic difference. Its large brakes use vented rotors in front for improved stopping power. All of these features give the Civic Type-R a high level of performance in its class.

Engine:	Inline 4
Engine location/ drive type:	F/F
Displacement:	1998 cc
Power @ rpm:	158 kW/ 212 hp @ 7800 rpm
Torque @ rpm:	202 Nm / 145 lb-ft @ 6500 rpm
Curb weight:	1204 kg / 2654 lb
Weight dist. front/rear %:	61/39
Top Speed:	235 kmh / 146 mph
Tires F/R	F: 205/45-17 R: 205/45-17

1972 LOTUS ELAN SPRINT

From 1962 to 1973, Lotus produced the Elan sports car. This little, lightweight two-seater was an ultramodern design, with a fiberglass body, steel backbone chassis, potent 4-cylinder engine, independent suspension, and disc brakes front and rear. In its original form the Elan was fast and nimble, and the Sprint model introduced in 1970 added extra power and performance from a twin-cam engine. After more than thirty years the Elan still looks like the quintessential small sports car.

Engine:	Inline 4
Engine location/ drive type:	F/R
Displacement:	1558 cc
Power @ rpm:	94 kW / 126 hp @ 6500 rpm
Torque @ rpm:	153 Nm / 113 lb-ft @ 5500 rpm
Curb weight:	719 kg / 1582 lb
Weight dist. front/rear %:	48/52
Top Speed:	185 kmh / 121 mph
Tires F/R	F: 155/80-13 R: 155/80-13

2004 MAZDASPEED RX-8

Mazdaspeed, the in-house performance division of Mazda Motor Corporation, offers a wide array of parts for the company's cars, and the Mazdaspeed RX-8 gets the full treatment, from body enhancements to suspension and engine parts. From its front fascia to its rear underspoiler and wing, this RX-8 gains in aerodynamic refinement. Its 18-inch magnesium alloy wheels are firmly located by a lowered coilover suspension with stiffer shocks and springs and larger antiroll bars. The chassis gains in stiffness from front and rear strut tower bars. The twin-rotor engine gets a lighter flywheel, double oil coolers, a special Powertrain Control Module, and modified exhaust system. All of this adds up to an uprated RX-8 with better performance and aggressive good looks.

Engine:	Twin-rotor Wankel
Engine location/ drive type:	F/R
Displacement:	1308 cc
Power @ rpm:	198 kW / 265 hp @ 8500 rpm
Torque @ rpm:	244 Nm / 180 lb-ft @ 5500 rpm
Curb weight:	1406 kg / 3093 lb
Weight dist. front/rear %:	52/48
Top Speed:	238 kmh / 148 mph
Tires F/R	F: 225/45-18 R: 225/45-18

1954 MERCEDES-BENZ 300SL GULLWING COUPE

One of the most famous designs in automotive history, the 300SL Gullwing Coupe was a roadgoing version of Mercedes' 1952 race car. The 300SL made a powerful impression with its handsome and purposeful shape and its very advanced specifications. Its 6-cylinder engine was the first production car engine to replace carburetors with fuel injection. Its fully independent suspension was state of the art. Its unique vertically-opening "gullwing" doors were not just a styling exercise, but a necessity since the car's lightweight tubular chassis covered the lower part of the area where a conventional door would be. The 300SL provided a very high level of performance for the time, with acceleration from 0-100 kmh (62 mph) in 10 seconds and a top speed of up to 260 kmh (161 mph), depending on the rear axle ratio. Futuristic in 1954, the 300SL remains one of the most admired and most sought-after twentieth-century cars.

Engine:	Inline 6
Engine location/ drive type:	F/R
Displacement:	2996 cc
Power @ rpm:	160 kW / 215 hp @ 5800 rpm
Torque @ rpm:	280 Nm / 206 lb-ft @ 4600 rpm
Curb weight:	1295 kg / 2849 lb
Weight dist. front/rear %:	51/49
Top Speed:	260 kmh / 161 mph
Tires F/R	F: 165/80-15 R: 165/80-15

2001 ACURA INTEGRA TYPE-R

The Integra Type-R is a lightened, high-performance version of the sporty front-wheel drive Integra hatchback. It features improved aerodynamics, a race-tuned suspension, larger wheels, high-performance tires, larger, more powerful brakes, Recaro seats, and a Momo steering wheel. Its engine benefits from numerous modifications, including revised pistons, connecting rods, valves, ports, and combustion chambers. To save weight, most sound-damping material is stripped out of the Type-R, along with the air conditioning. The result is a street machine with nearly race car performance.

Engine:	Inline 4
Engine location/ drive type:	F/F
Displacement:	1797 cc
Power @ rpm:	145 kW / 195 hp @ 8000 rpm
Torque @ rpm:	176 Nm / 130 lb-ft @ 7500 rpm
Curb weight:	1197 kg / 2633 lb
Weight dist. front/rear %:	62/38
Top Speed:	230 kmh / 143 mph
Tires F/R	F: 195/55-15 R: 195/55-15

2005 FORD MUSTANG GT

This muscular American car celebrates the Mustang's forty-year history in a version that is thoroughly up to date. Its 300-hp aluminum V8, five-speed transmission, MacPherson-strut front suspension, updated solid-axle rear suspension, and larger disc brakes with ventilated rotors in front combine the new and the old, with concessions to nostalgia and to modern performance expectations.

Engine:	V8
Engine location/ drive type:	F/R
Displacement:	4601 cc
Power @ rpm:	224 kW / 300 hp @ 6000 rpm
Torque @ rpm:	434 Nm / 320 lb-ft @ 4500 rpm
Curb weight:	1568 kg / 3450 lb
Weight dist. front/rear %:	54/46
Top Speed:	240 kmh / 149 mph
Tires F/R	F: 235/55-17 R: 235/55-17

1961 JAGUAR E-TYPE S1

When the E-type Jaguar burst on the automotive scene in 1961, it caused a sensation. Low and sleek, it was clearly the successor of the beautiful Jaguar C- and D-type racers that had won at Le Mans and elsewhere in the 1950s. It was also ahead of its time for a production car. Capable of 150 mph in stock trim, its good looks and performance—and its relatively low price—made it instantly popular. Its strong but light monocoque structure, twin-cam engine, independent suspension, front and rear disc brakes, and general refinement made many sports cars of the era seem antiquated.

Engine:	Inline 6
Engine location/ drive type:	F/R
Displacement:	3781 cc
Power @ rpm:	198 kW / 265 hp @5500 rpm
Torque @ rpm:	353 Nm / 260 lb-ft @ 4000 rpm
Curb weight:	1219 kg / 2682 lb
Weight dist. front/rear %:	49/51
Top Speed:	241 kmh / 150 mph
Tires F/R	F: 175/90-15 R: 175/90-15

2005 LOTUS EXIGE

This giant-killer exemplifies the Lotus tradition of small size, light weight, and high performance. It is the lightest car in its class in *Forza Motorsport 2*. Its fiberglass body and aluminum frame, aerodynamic refinements, the same tuned suspension used in the sport version of the Elise roadster, and mid-mounted Toyota engine combine to give this little coupe aggressive handling and the overall performance drivers expect from a Lotus car.

Engine:	Inline 4
Engine location/ drive type:	Mid/R
Displacement:	1796 cc
Power @ rpm:	141 kW / 189 hp @ 7800 rpm
Torque @ rpm:	180 Nm / 133 lb-ft @ 6800 rpm
Curb weight:	875 kg / 1925 lb
Weight dist. front/rear %:	38/62
Top Speed:	269 kmh / 167 mph
Tires F/R	F: 195/50-16 R: 225/45-17

2006 VAUXHALL ASTRA VXR

The Opel-based Astra is sold worldwide as an Opel, Vauxhall, Holden, or Chevrolet. The hottest of all Astras is the 2-liter, 240-hp VXR, which provides a very high level of performance. Its big brother is the Monaro VXR, based on the Monaro produced by Holden, GM's Australian subsidiary. Both reflect the philosophy behind the VXR series of cars, in which each model is a focused performance machine with the soul of a race car, but optimized for road use.

Engine:	Inline 4
Engine location/ drive type:	F/F
Displacement:	1998 cc
Power @ rpm:	180 kW / 241 hp @ 5600 rpm
Torque @ rpm:	320 Nm / 236 lb-ft @ 2400 rpm
Curb weight:	1393 kg / 3065 lb
Weight dist. front/rear %:	54/46
Top Speed:	241 kmh / 152 mph
Tires F/R	F: 225/40-18 R: 225/40-18

2005 ASTON MARTIN DB9 COUPE

This sleek grand tourer uses the same engine as the Aston Martin Vanquish. With its handsome aerodynamic shape and 6 liters of V12 power, this latest member of the DB series is the fastest and most powerful yet, with sports car handling and hand-built exclusivity. Its aluminum structure makes it lighter than its DB7 predecessor, with excellent acceleration off the line and a high top speed. Surrounding its driver in leather-lined luxury, the DB9 carries on the Aston Martin tradition of high performance and grand touring comfort.

Engine:	V12
Engine location/ drive type:	F/R
Displacement:	5935 cc
Power @ rpm:	335 kW / 450 hp@ 6000 rpm
Torque @ rpm:	570 Nm / 420 lb-ft @ 5000 rpm
Curb weight:	1760 kg / 3872 lb
Weight dist. front/rear %:	50/50
Top Speed:	300 kmh / 186 mph
Tires F/R	F: 235/40-19 R: 275/35-19

2006 AUDI RS 4

This ultimate version of the Audi A4 sports sedan features V8 power and the latest version of the quattro all-wheel-drive system. With improved aerodynamics and a powerful dose of racing technology, the RS 4 combines high performance with civilized driving qualities for the street and interior amenities. Its direct-injection V8, large and well-ventilated disc brakes, lowered ride height, carefully calibrated suspension, and attention to aerodynamic detail make it a strong competitor and a potent daily driver.

Engine:	V8
Engine location/ drive type:	F/AWD
Displacement:	4163 cc
Power @ rpm:	309 kW / 420 hp @ 7800 rpm
Torque @ rpm:	430 Nm / 317 lb-ft @ 5500 rpm
Curb weight:	1650 kg / 3638 lb
Weight dist. front/rear %:	53/47
Top Speed:	250 kmh / 155 mph
Tires F/R	F: 255/40-18 R: 255/40-18

2004 BENTLEY CONTINENTAL GT

Introduced in 2003, the Continental GT is an ultramodern interpretation of the traits that have always defined Bentley cars: luxury, large size, high power, and performance. Its compact, 12-cylinder, twin-turbocharged engine provides strong acceleration from rest to 200 mph. All-wheel drive helps transmit abundant power to the road, and keeps the chassis balanced for a high level of handling. Its powerful brakes allow for equally impressive deceleration. The Continental GT's passengers are cocooned in luxury, but its performance keeps the driver's attention focused on the road.

Engine:	W12
Engine location/ drive type:	F/AWD
Displacement:	5998 cc
Power @ rpm:	411 kW / 552 hp @ 6100 rpm
Torque @ rpm:	650 Nm / 479 lb-ft @ 1600 rpm
Curb weight:	2385 kg / 5258 lb
Weight dist. front/rear %:	59/41
Top Speed:	318 kmh / 198 mph
Tires F/R	F: 275/40-19 R: 275/40-19

2006 PORSCHE CAYMAN S

The Cayman S hatchback coupe shares many design features with the legendary 911, and combines high performance with outstanding stability. Its 3.4-liter flat six is mounted in the center of the car, and its chassis provides balanced handling that is direct and responsive for the driver, as well as comfortable and informative. Carefully designed cockpit ergonomics and Porsche's high standards of active and passive safety allow driver and passenger to focus on the driving experience. The distinctive appearance of the Cayman S blends concave and convex surfaces in a striking design that is new and yet instantly recognizable as a member of the Porsche family.

Engine:	Flat 6
Engine location/ drive type:	Mid/R
Displacement:	3386 cc
Power @ rpm:	217 kW/ 295 hp @ 6250 rpm
Torque @ rpm:	340 Nm / 251 lb-ft @ 4400-6000 rpm
Curb weight:	1340 kg/2948 lb
Weight dist. front/rear %:	45/55
Top Speed:	275 kmh/171 mph
Tires F/R	F: 235/40-18 R: 265/40-18

1999 DODGE VIPER GTS ACR

In 1996, Dodge introduced a coupe version of the Viper sports car, and produced a racing version, the GTS-R, which won numerous victories in the GT2 class, including Le Mans in 1998. The next year Dodge introduced a limited edition American Club Racer model of the stock GTS coupe. In the GTS ACR the Viper's 8-liter V10 gains some additional horsepower and torque through improved breathing, sheds some weight by omitting the air conditioning and sound systems, and gets improved handling from GTS-R-based suspension components. The result is a street-legal, race-ready super coupe, complete with five-point racing-style seat belts.

Engine:	V10
Engine location/ drive type:	F/R
Displacement:	7986 cc
Power @ rpm:	343 kW / 460 hp @ 5200 rpm
Torque @ rpm:	678 Nm / 500 lb-ft @ 3700 rpm
Curb weight:	1565kg / 3450 lb
Weight dist. front/rear %:	48/52
Top Speed:	298 kmh / 185 mph
Tires F/R	F: 275/35-18 R: 335/30-18

2002 ENZO FERRARI

Between 2002 and 2004, Ferrari produced just 400 of these Italian supercars, which commemorate the company's founder. The Enzo Ferrari's combination of technology and aesthetics makes it one of the world's most desirable high-performance cars. It borrows transmission and brake technologies from Formula One race cars, and its exotic shape consists of carbon fiber body panels for a race-car-like strength and lightness, while computer-controlled active aerodynamics keep it stable at extremely high speeds. Its combination of good looks, power, and handling put the Enzo Ferrari at the pinnacle of the long line of high-performance cars from this legendary manufacturer.

Engine:	V12
Engine location/ drive type:	Mid/R
Displacement:	5999 cc
Power @ rpm:	485 kW / 650 hp @ 7800 rpm
Torque @ rpm:	658 Nm / 485 lb-ft @ 5500 rpm
Curb weight:	1476 kg / 3247 lb
Weight dist. front/rear %:	44/56
Top Speed:	351 kmh / 218 mph
Tires F/R	F: 245/35-19 R: 345/35-19

2005 FORD GT

The Ford GT is a twenty-first-century supercar in terms of design, construction, and its tractability for street use. This ultramodern machine is powered by a supercharged 5.4-liter DOHC V8 that gives it a distinctly American flavor—and brutal acceleration. Its aluminum structure and body panels provide strength, lightness, and rigidity, and its forged aluminum suspension helps keep the tires planted on the road at high speed. Initial assembly of this roadworthy reinterpretation of Ford's iconic racer is built by Saleen, Inc., and then handed off to Ford, which installs the engine, transmission, and interior. When production ends late in 2006, Ford will have delivered around 4,000 of these American exotics.

Engine:	V8
Engine location/ drive type:	Mid/R
Displacement:	5409 cc
Power @ rpm:	410 kW / 550 hp @ 6500 rpm
Torque @ rpm:	678 Nm / 500 lb-ft @ 3750 rpm
Curb weight:	1522 kg / 3350 lb
Weight dist. front/rear %:	43/57
Top Speed:	326 kmh / 205 mph
Tires F/R	F: 235/45-18 R: 315/40-19

2001 TVR TUSCAN R

The Tuscan R boasts 450 hp and enhanced aerodynamics to produce race car performance, but customers can have their cars built to order, configured as a roadgoing grand tourer or as a race-ready competitor. TVR calls this "bespoke manufacturing," with customers consulted on matters from color and trim to suspension tuning. The Tuscan R can be ordered with four seats or two surrounded by a full roll cage, and customers can choose custom leather or racing carbon Kevlar. The chassis is made of stressed aluminum honeycomb panels, and the body panels are carbon and Kevlar composite. The Tuscan R combines low weight, high power, and aggressive aerodynamics and suspension in a package as attractive or as purposeful as the individual owner wishes.

Engine:	Inline 6
Engine location/ drive type:	F/R
Displacement:	3996 cc
Power @ rpm:	335 kW / 450 hp @ 7500 rpm
Torque @ rpm:	474 Nm / 350 lb-ft @ 5250 rpm
Curb weight:	1060 kg / 2332 lb
Weight dist. front/rear %:	55/45
Top Speed:	320 kmh / 199 mph
Tires F/R	F: 225/35-18 R: 255/35-18

2002 KOENIGSEGG CC8S

This luxurious 230-mph supercar features a custom leather interior and fitted luggage, along with a host of high-tech features seldom seen outside of advanced race cars. Koenigsegg introduced the 806-hp CCR in 2004, and the CCX, which delivers the same performance using 91-octane fuel and meets even more stringent emissions requirements, in 2006. Koenigsegg creates each car in its very limited production specifically for each customer. Like racing cars, these formidable vehicles can be set up to perform on any track or set of road conditions. Unlike racing cars, they are well-mannered on the street and offer a level of luxury no race car driver ever enjoyed.

Engine:	V8
Engine location/ drive type:	Mid/R
Displacement:	4601 cc
Power @ rpm:	490 kW / 655 hp @ 6800 rpm
Torque @ rpm:	750 Nm / 553 lb-ft @ 5000 rpm
Curb weight:	1175 kg / 2585 lb
Weight dist. front/rear %:	43/57
Top Speed:	390 kmh / 240 mph
Tires F/R	F: 255/40-18 R: 335/30-20

2003 SUBARU CUSCO ADVAN IMPREZA

This Japanese GT300 car is one hot Impreza. Yuji Kase's Cusco brand is a major tuner for the Subaru Impreza line, and this racing rear-wheel-drive compact adds significant performance to an already potent platform. Its intercooled 300-hp engine is upgraded with dry-sump lubrication, a single ball-bearing IHI turbo, a reprogrammed ECU, and an oil cooler. The power gets to the rear tires through a triple-plate carbon clutch and a six-speed sequential transmission mounted in front of the limited-slip differential. The suspension features stiffer springs and dampers, and the stopping power comes from big disc brakes with water-cooled 6-piston calipers. This adds up to a very competitive package in the All-Japan Grand Touring Championship.

Engine:	Flat 4
Engine location/ drive type:	F/R
Displacement:	1994 cc
Power @ rpm:	224 kW / 300 hp @ 6000 rpm
Torque @ rpm:	392 Nm / 290 lb-ft @ 4500 rpm
Curb weight:	1140 kg / 2508 lb
Weight dist. front/rear %:	50/50
Top Speed:	343 kmh / 213 mph
Tires F/R	F: 280/40-18 R: 280/40-18

2002 BMW MOTORSPORT M3-GTR (STREET VERSION)

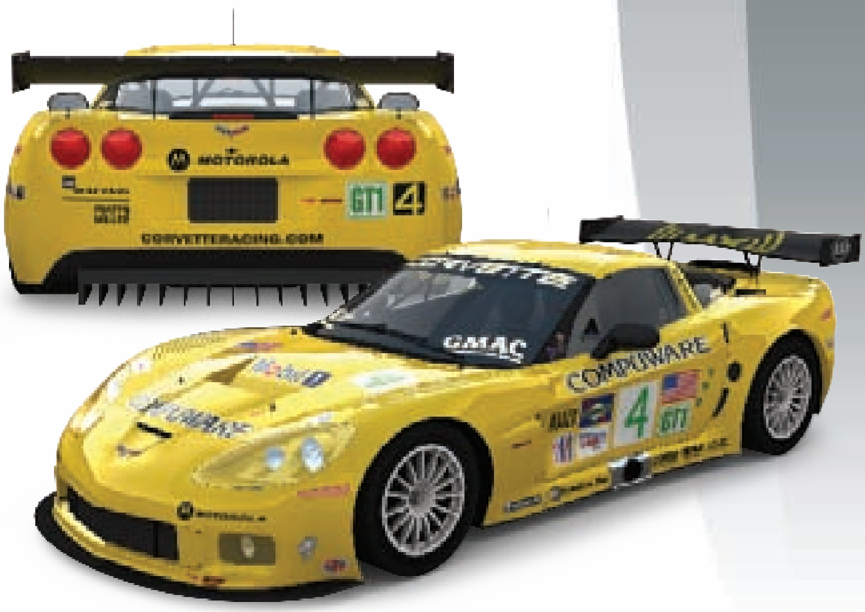
This purist M version of the BMW 3-series is about performance with very little compromise. Lightened, stripped of most amenities, and fitted with V8 power and carbon fiber body panels, this two-seater has been a successful competitor in the American Le Mans Series. The M3-GTR can be licensed for the street, but it borrows many aerodynamic, suspension, and engine parts from all-out racing BMWs. Its lowered suspension, dry-sump lubrication, two-disc clutch, and improved cooling, combined with a spartan interior, make it a formidable competitor for those who have the skill to use its high performance on the track.

Engine:	V8
Engine location/ drive type:	F/R
Displacement:	3997 cc
Power @ rpm:	283 kW / 380 hp @ 7000 rpm
Torque @ rpm:	390 Nm / 269 lb-ft @ 4500 rpm
Curb weight:	1350 kg / 3038 lb
Weight dist. front/rear %:	51/49
Top Speed:	250 kmh / 155 mph
Tires F/R	F: 225/40-19 R: 255/35-19

2006 CHEVROLET CORVETTE C6.R

The Corvette C6.R race car debuted in 2005, and soon picked up where the C5.R left off—winning races. C6.Rs took first and second in the GT1 class at Le Mans, and performed brilliantly to dominate their class in the American Le Mans Series. The C6.R trumps the technology of its predecessor, with improved aerodynamics and a refined 7-liter V8. The engine uses dry-sump lubrication, and gains performance from improved porting and titanium valves and connecting rods. The C6.R also benefits from the new C6 Corvette's suspension geometry and overall reduction in size and drag, and builds on those qualities to become the most capable Corvette ever.

Engine:	V8
Engine location/ drive type:	F/R
Displacement:	7011 cc
Power @ rpm:	433 kW / 580 hp @ 5400 rpm
Torque @ rpm:	827 Nm / 610 lb-ft @ 4400 rpm
Curb weight:	1100 kg / 2420 lb
Weight dist. front/rear %:	50/50
Top Speed:	306 kmh / 190 mph
Tires F/R	F: 290/35-18 R: 310/40-18



2005 HONDA NSX-R

The original NSX caused quite a stir in the automotive world when it was introduced in 1990. A stunning performer suitable for everyday street driving, its striking good looks were based on aerodynamic efficiency, and its avant-garde V6 gave it performance usually associated with larger-displacement engines. The original NSX demonstrated Honda's intention to compete with the world's best automakers, but Honda decided to take its design a step further. The NSX-R, introduced in 1992 and updated in 2002, is a lightened, higher-performance version of this already super car, built exclusively for the Japanese market. It features the original car's lightweight aluminum chassis, body, and suspension, and the VTEC variable valve timing system (the first in a production car). Its improved suspension and a weight reduction of around 120 kg make it an aggressive competitor on the track.

Engine:	V6
Engine location/ drive type:	Mid/R
Displacement:	3179 cc
Power @ rpm:	216 kW / 290 hp @ 7300 rpm
Torque @ rpm:	304 Nm / 224 lb-ft @ 5300 rpm
Curb weight:	1300 kg / 2860 lb
Weight dist. front/rear %:	43/57
Top Speed:	282 kmh / 175 mph
Tires F/R	F: 215/40-17 R: 255/40-17

1965 SHELBY COBRA 427 S/C

Weighing a little over a ton and propelled by a 7-liter V8, the Cobra 427 S/C is a beautiful brute, and a handful to drive. To handle the added power and torque of the big V8, Shelby updated the Cobra with a new, larger tubular chassis and replaced the leaf spring suspension with coil springs and upper and lower wishbones. This Cobra also had a wider body with flaring wheel arches to accommodate bigger tires, which helped to get the power to the road. Not for the faint of heart, this potent machine added to the reputation of the Cobra as the ultimate sports car of its era.

Engine:	V8
Engine location/ drive type:	F/R
Displacement:	7010 cc
Power @ rpm:	362 kW / 485 hp @ 6200 rpm
Torque @ rpm:	678 Nm / 500 lb-ft @ 4250 rpm
Curb weight:	1068 kg / 2350 lb
Weight dist. front/rear %:	50/50
Top Speed:	241 kmh / 150 mph
Tires F/R	F: 235/60-15 R: 275/50-15

2004 SALEEN S7

The S7, Saleen's first completely original design, is available as an all-out race car, but since 2001 Saleen has offered a more luxurious roadgoing version. Whether intended for road or track, the S7 is a true American-made exotic, attaching carbon fiber bodywork to a hybrid chassis that combines aluminum honeycomb panels with a steel spaceframe. The normally aspirated S7 is powered by a 7-liter, 550-hp V8.

Engine:	V8
Engine location/ drive type:	Mid/R
Displacement:	7007 cc
Power @ rpm:	410 kW / 550 hp @ 5900 rpm
Torque @ rpm:	712 Nm / 525 lb-ft @ 4000 rpm
Curb weight:	1300 kg / 2856 lb
Weight dist. front/rear %:	40/60
Top Speed:	386 kmh / 240 mph
Tires F/R	F: 275/30-19 R: 345/25-20

1997 McLAREN F1 GT

This 240-mph supercar uses technology from Formula One racing, including a strong, lightweight carbon fiber monocoque structure. Its 6.1-liter, 627-hp BMW V12 gives this exotic three-seat coupe tremendous speed and acceleration. In 1995, F1s took first, third, fourth, and fifth places at Le Mans, proving that a million dollars also buys impressive durability, along with racing capability. In the last year of production, McLaren built three F1 GTs, essentially street versions of the F1 GTR race car, with a longer, wider, lower body and lengthened front and rear overhangs that increase downforce. The F1 GT is the rarest of an already rare breed.

Engine:	V12
Engine location/ drive type:	Mid/R
Displacement:	6064 cc
Power @ rpm:	468 kW / 627 hp @ 7500 rpm
Torque @ rpm:	651 Nm / 480 lb-ft @ 5600 rpm
Curb weight:	1,120 kg / 2,464 lb
Weight dist. front/rear %:	41/59
Top Speed:	335 kmh / 208 mph
Tires F/R	F: 275/35-18 R: 345/35-18

An Interview with Audio Lead Greg Shaw

Audio Lead Greg Shaw's job is to re-create the sounds of automobile racing, to immerse players in a world that sounds satisfyingly real. It's not a simple process, but one that has made him a permanent student of the way things sound and the reasons why they sound the way they do. Here he provides a detailed look at this complex task, from recording hundreds of cars in dyno sessions to accurately reproducing all the components of cars in action, from engines and tires to transmissions and turbochargers. He also reveals the challenges of re-creating collision sounds with various materials taking damage, and discusses how putting the right music into the game enhances the player experience.

Q: You've gone to great lengths to get detailed audio to re-create the overall sound for each car. What sounds are you capturing to re-create what cars really sound like?

What we're trying to do is analyze the sound of a car in its entirety, to break it apart and reconstruct it in the game, creating an overall model of each car's sound. In terms of components, there's forced induction—superchargers and turbochargers, and normally aspirated engine sounds—and different levels of exhaust systems based on various upgrades. It really breaks down into two parts: capturing the source—recording the audio—of that component or car, and then there's reconstructing or re-implementing it. It's really two battles—if you get one of them wrong, the end result is bad, no matter how well the other part works. A good case in point is transmissions. We've struggled to get good transmission recordings because we need to record the transmission without the exhaust sounds, or dyno sounds, or any other mechanical sounds; just the gear sounds under certain conditions.

"One thing I'm pretty proud of is the different sounds from upgraded cars, with different exhaust systems and other upgrade parts. There are numerous permutations; I wouldn't want to be the audio tester!"

Q: That's practically impossible, since you need to have all of that working for the transmission to be working.

You'd think so. But there are some things you can do, like placing the microphones in certain ways to reject exhaust sounds, but you only find racing transmissions in cars with relatively loud exhaust systems, so there aren't a lot of options in terms of placing mics. So we've had to get creative. We have a couple of guys who are pretty good at that. We have an ASE-certified mechanic under contract who helps us understand why things work the way they do from a physics standpoint. We have another guy who's a real gearhead, good at understanding these things. So we get creative. We identify the need for a source recording and figure out how to get it. Sometimes that means fabricating parts, or asking the larger car community for parts we can borrow to put these contraptions together. It's a constant learning experience, even when we think we know how it works.

Getting back to the transmission, we tried to record a couple of transmissions and we got pretty close to getting the sound we want, and then discovered something unique about the sound we'd never heard before, so we had to reevaluate how we re-create the transmission sound in the game.

Q: You guys are pushing the envelope here—not many racing games go for that level of detail.

I don't know of very many that do. The only one that comes to mind is another Microsoft game, *Project Gotham Racing*. It's a great game for audio, and we have a healthy competition and a good relationship. It's a shared journey into the world of audio and cars for both of us. They help us and we help them. A lot of what I see us doing is improving audio in the whole game space. We have a family of Microsoft games that allows us to do that without a lot of competitive problems, so we have a general effort to improve audio in games.

Q: What are the most significant problems in capturing audio reality?

Before I came to Microsoft I worked on sound for a lot of fictional games, and that was a lot of fun. I came here and thought I knew it all, and started working on sounds for simulations. It's a whole different school of thought, a different way of going about things. Here if you're re-creating a sound from real life, it has to sound the way it does in real life. There's creating the sound, and then there's how it reacts in gameplay: how it changes in timbre, pitch, and volume. What isn't widely known is how mechanical sounds react. What causes the transmission sound? I find it much more challenging than creating fictional sounds.

Q: Has this changed you as a listener?

It's caused me to be more of a student of how things sound, trying to understand why things sound the way they do.

Q: So to understand a sound, you have to understand at a very basic level what's happening to make the sound.

And along the way you learn about the assumptions you're making. You're always making more assumptions, and your assumptions should be getting more accurate. Let's say there's a need for the sound of a gun in a game. You capture reference audio, examine it under several physical conditions, and then decide to re-create the gun sound from scratch for a more cinematic effect, to sound bigger than life. You have to have a basis for why the gun should sound the way it does.

Q: Is that approach appropriate for a racing simulation?

That's part of being a student of audio, of why things sound the way they do. We do that for the *Forza Motorsport* games. For example, we went to the ALMS race at Portland, Oregon, and recorded some sounds, but 90% of the recordings are for reference, so we can study how things sound. I had a sound level meter, and was studying the sound levels as the cars passed by from very specific distances. After all that we apply a formula to project how loud the sound will be at a greater distance.

Q: At a race, one thing that impresses everyone is how visceral and violent race cars sound with straight pipes. How do you re-create that kind of sensation in the game?

Recording the car is only half the battle. You've got to put the sound into the game correctly. The final stage is mixing the sound. Dynamic range—how quiet your quietest sounds are and how loud the loudest sounds are—is an issue. If your sound is at a comfortable level, then a loud sound startles you. A lot of it is in the mix. It's a tricky subject because you've got to have a scale. The loudness you hear at the track isn't going to be a pleasant listening level when you're racing in a game.

Q: You've recorded hundreds of cars. How do you capture the sound of a car so you can use it in-game?

The *Project Gotham Racing* team did a lot of experimentation, and we learned a lot from their experimentation. It basically comes down to putting a car on the dynamometer, putting resistance against the car so it's under load, and then running the car at a constant rpm for a certain amount of time so we can record it; that, coupled with proper mic placement and the right recording equipment. Then we bring it back to the studio and cut up the different sound loops and put them into the game. This is where it gets hard to explain, but it's where our "secret sauce" is—the way we put them into the game is unique.

In general, that's what racing games have been doing for quite awhile. We wanted to take it to the next level and experiment with ways to attach our sounds to the cars in the game and make sure they react to the physics accurately to provide the right feedback to the player. That's where audio really shines in *Forza Motorsport*. Fidelity is important, but feedback to the user is even more important. That's the difference between movies and games. As a player, if you pay attention to the audio, you will improve your racing skills, and that's what matters most.

Q: What else are you doing to raise the bar?

An additional challenge for *Forza Motorsport* is allowing users to upgrade their cars. Not only do we have to get the right sound for the car in stock trim, but the sound also has to evolve as you upgrade the car. You can't imagine the number of possible permutations. So we have to peel another layer off the onion to understand when you change a component on a car, how that is going to change the sound. How do we build that sound; how do we record it in the first place? How do we implement it? We've recorded superchargers, turbochargers, and transmissions separately, in isolation. Then we put those sounds into the cars for which we've already recorded the engines.

Q: Did you have to build any special contraptions for recording superchargers?

Our resident gearhead, Joel, is pretty innovative, and good at understanding physics at a certain level and interpreting how it might cause sound to change. He built a rig that allows us to take superchargers out of cars, put them on this rig, and spin them so we can record the sound isolated from the rest of the car sounds. For turbochargers we went to a turbo manufacturer and they built a special rig so we could record them in isolation.

Q: You've also recorded collision sounds. How did you go about it?

The collision session was a whole lot of fun. In version one the collision audio wasn't as good as we wanted. We dropped a car from a crane, but it wasn't moving fast enough to yield the sounds we wanted. And we didn't implement the sound to the degree we wanted. So we decided we needed to learn more about why collisions sound the way they do. The best way to do that is to go to a crash test facility—really a crash reconstruction facility. We needed to understand the different permutations of collisions at different velocities, and the types of materials in the cars, and put together a plan before we went to the facility in California and reconstructed crashes and recorded them. We were able to get some incredible audio and learned it's not just the velocity, but also the angle of the collision and the length of the actual collision sound. We were also able to understand scrapes—what causes their volume and pitch levels. We recorded scraping across various materials types: tire walls, aluminum, concrete, carbon fiber and other composites, and so on.

Q: How about music in the game? What are the qualities of a song that makes it good music for driving?

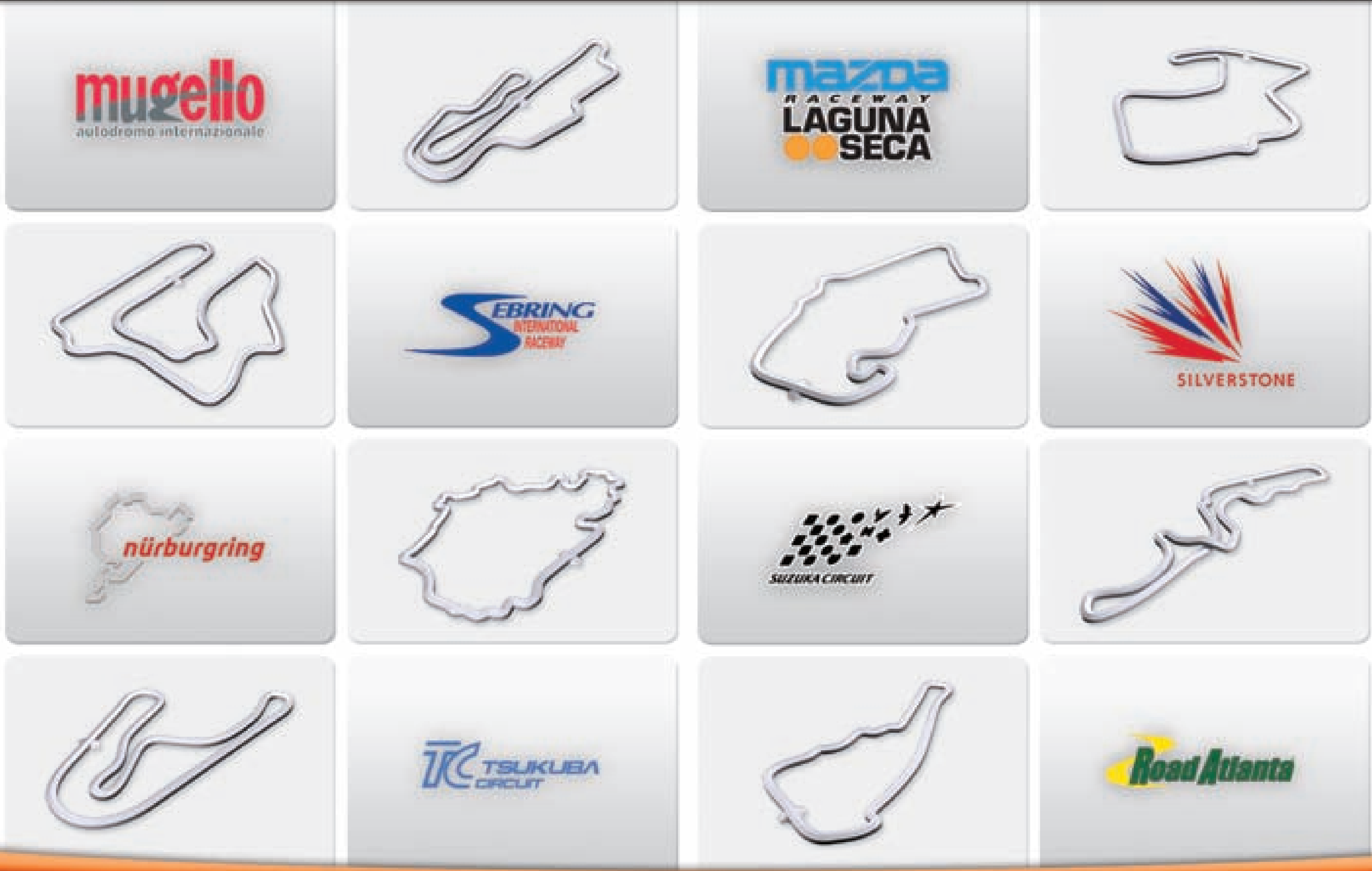
Music was interesting in version one. The process kept evolving, but not always along the right path. This time we decided to do something to enhance the game in a different way by licensing music that fits the game, instead of working with a composer. We went to artists whose music we felt fits with *Forza Motorsport*. The general vision of the soundtrack is more electronic, a little tighter. We have more than forty licensed tracks, chosen from hundreds of songs we reviewed. We focused a lot on the European audience without alienating the American audience—it's a fine line. In version one the music had a steady beat and high energy, and we wanted to keep those elements for version two.

Q: What aspect of the audio are you most proud of in Forza Motorsport 2? What are the biggest breakthroughs?

We've raised the bar at so many levels. We've recorded the cars the way they should be recorded, we've recorded the components in isolation, we've gotten access to the right cars, and we've built a community. One thing I'm pretty proud of is the different sounds from upgraded cars, with different exhaust systems and other upgrade parts. There are numerous permutations; I wouldn't want to be the audio tester!

None of this would have been possible without the incredible efforts of everyone involved with the audio production and development for *Forza Motorsport 2*. What I am most proud of is the team I've put together to work on the audio for the game. They are all top-notch.

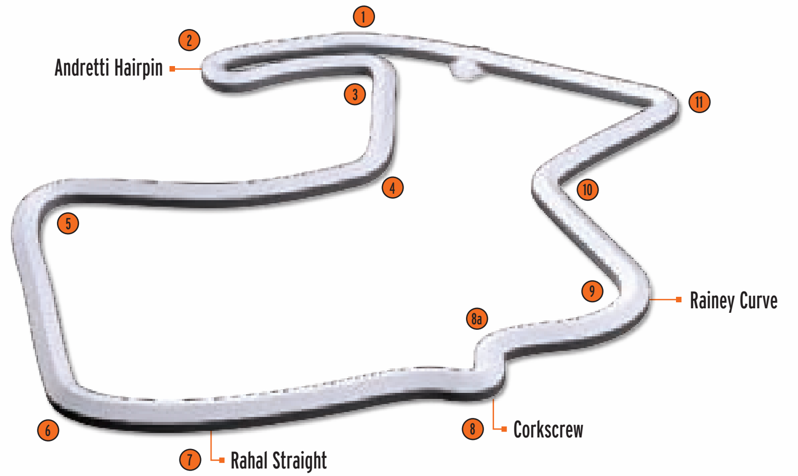
REAL-WORLD TRACKS



MAZDA RACEWAY LAGUNA SECA

In *Forza Motorsport 2* you can try your skills and challenge your opponents on a large number of racing circuits. These include fictional and city tracks, and the eight famous real-world tracks described here. They range from legendary circuits like Germany's Nürburgring to challenging road and oval courses in the United States, Italy, Great Britain, and Japan, including:

- Mazda Raceway Laguna Seca
- Mugello Autodromo Internazionale
- Nürburgring Nordschleife
- Road Atlanta
- Sebring International Raceway
- Silverstone
- Suzuka Circuit
- Tsukuba Circuit



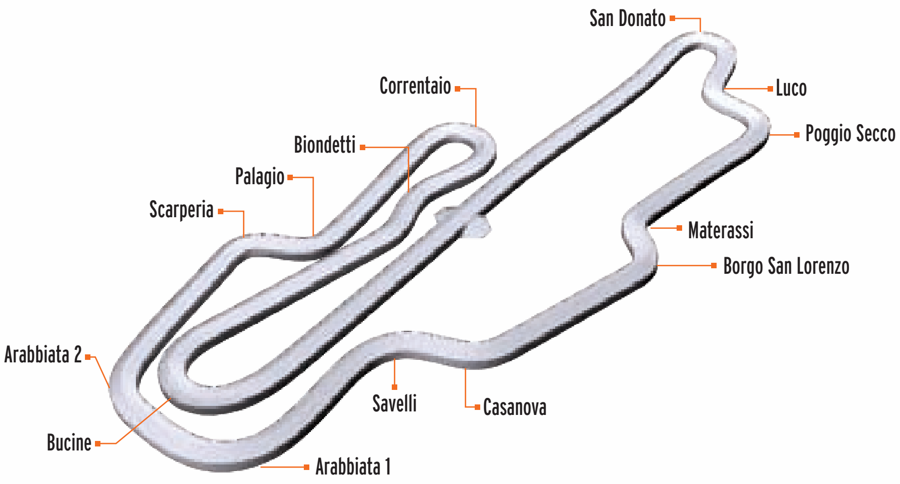
Mazda Raceway Laguna Seca is one of the most famous race tracks in the United States. Built in 1957, this spectacular 2.24-mile (3.58-km) course near Monterey, California combines high-speed sections with some of the trickiest turns in the business, including turn 8, the infamous "Corkscrew." This precipitous left-right downhill plunge is a major part of the track's 300-foot elevation change in the course of each lap. It's also a major test of driver courage, as keeping your foot on the throttle seems counter-intuitive, perhaps suicidal. Alex Zanardi's overtaking maneuver there in 1996, widely known as "The Pass," demonstrated the kind of skill and courage required to win on this unique course.

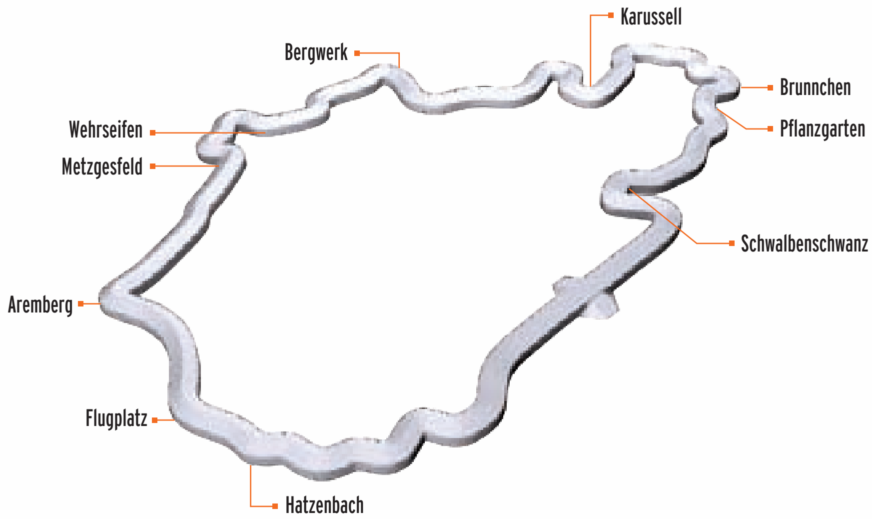
Track Specs:

Name:	Mazda Raceway Laguna Seca
Location:	United States
Date opened:	1957
Length:	2.24 miles (3.58 km)

MUGELLO AUTODROMO INTERNAZIONALE

NÜRBURGRING NORDSCHLEIFE





Track Specs:

Name:	Mugello Autodromo Internazionale
Location:	Italy
Date opened:	Current course: 1974 Original course: 1914
Length:	3.25 miles (5.25 km)

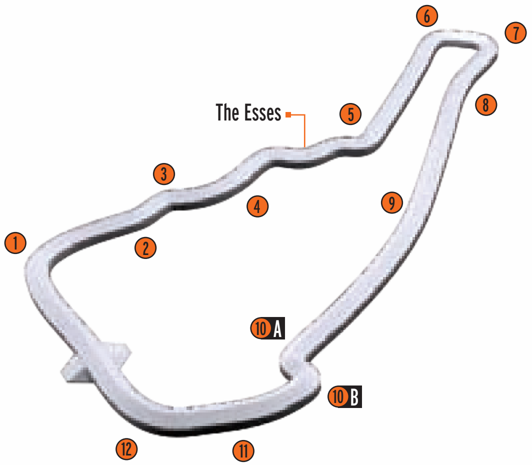
The Italian Mugello Autodromo Internazionale took its current form during the 1970s under the ownership of Ferrari, which uses the course as its test track, along with Ducati and other manufacturers. The facility also hosts both motorcycle and automobile racing. Originally, in 1914, Mugello was a 41-mile (66-km) track on dusty public roads north of Florence in Tuscany. One of the early race winners on the old course was Enzo Ferrari in 1921, driving an Alfa Romeo. During the 1950s it was shortened to 11.8 miles (19 km). Now the 3.25-mile (5.25-km) length of this modern circuit is divided evenly between its fifteen turns and straights of varying length, and includes an altitude change of 135 feet (41.2 m).

The Nürburgring is one of the world's oldest and most picturesque racing venues. The original Nordschleife (the North circuit), built in 1927, is one of the most challenging tracks in the world, covering 12.9 miles (20.8 km) with more than seventy turns winding through the heavily forested Eifel mountains near the Belgian border. Formula One champion Jackie Stewart called it "The Green Hell," as many drivers came to grief meeting its dangers. Every year 220 cars compete in the Nürburgring 24-Hour race. Between racing events, the Nordschleife is a one-way public toll-road. Anyone in any car can charge through the mountains with visions of great drivers like Fangio, Moss, Clark, or Stewart in their heads.

Track Specs:

Name:	Nürburgring Nordschleife
Location:	Germany
Date opened:	1927
Length:	12.9 miles (20.8 km)

ROAD ATLANTA

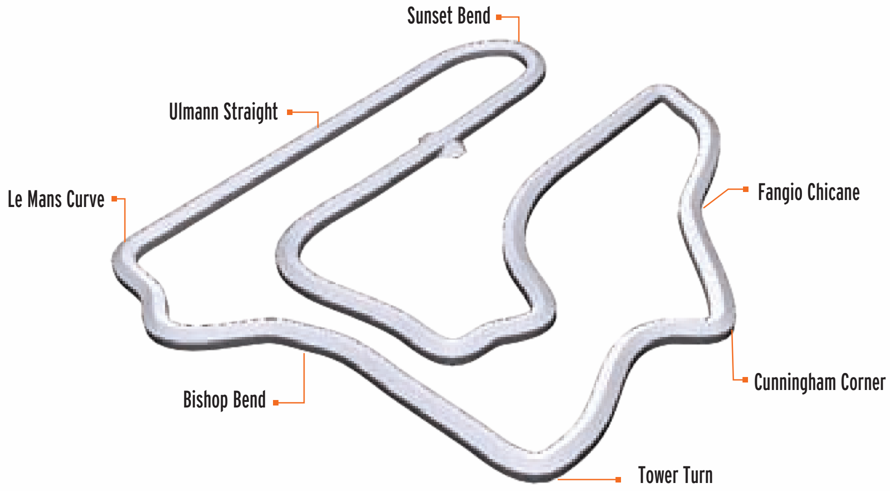


Track Specs:

Name:	Road Atlanta
Location:	United States
Date opened:	1970
Length:	2.54 miles (4 km)

This 2.54-mile (4-km) road course is located in Braselton, Georgia, north of Atlanta. Owned by the Panoz Motor Sport Group, it is the site of numerous racing events, including the American Le Mans Series. A lap of the track includes significant elevation changes and twelve turns of varying difficulty, including the fast downhill Esses between turns four and five, turn eleven (a blind right-hander over the crest of a hill), and a long, fast back straight. Road Atlanta is a fast course, hard on the tires and on the brakes with its downhill braking zones.

SEBRING INTERNATIONAL RACEWAY



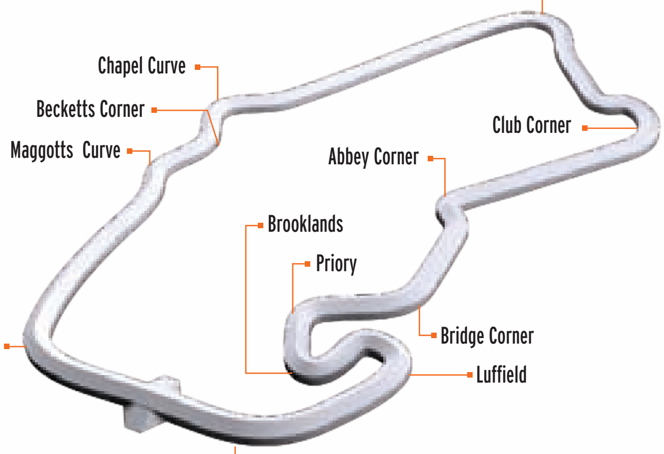
This Florida race course north of Miami, built on the site of the U.S. Army Air Force's Hendricks Field, is the oldest permanent road racing track in North America, hosting its first race in 1950. Its most famous ongoing event, the Sebring 12-Hours, began in 1952. Sebring hosted the U.S. Grand Prix in 1959, and has been part of the American Le Mans Series since 2000. The original airfield circuit was 5.2 miles (8.4 km) long, but over the years the layout has changed. Since 1999, when the Panoz Motor Sport Group acquired the circuit, it has been made wider but shorter, at 3.7 miles (5.95 km), with seventeen turns. Long straights and a mix of fast and slow corners make Sebring a setup and driving challenge. Its bumpy, uneven track surface is a major test of car reliability and driver stamina.

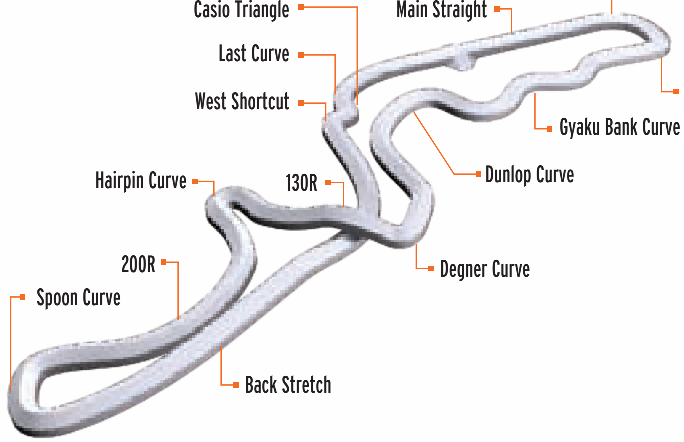
Track Specs:

Name:	Sebring International Raceway
Location:	United States
Date opened:	1950
Length:	3.7 miles (5.95 km)

SILVERSTONE

SUZUKA CIRCUIT





Track Specs:

Name:	Silverstone
Location:	United Kingdom
Date opened:	1948 (current course 1991)
Length:	Main course: 3.19 miles (5.1 km) Short course: 1.77 miles (2.8 km)

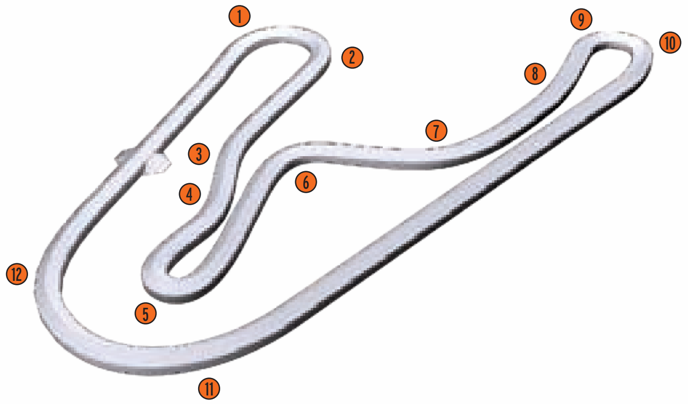
Home of the British Grand Prix in most years since 1948, the prestigious Silverstone circuit started out as a Royal Air Force bomber base in 1943. Until 1950 the cars raced on the runways, then on the airfield perimeter road for many years. The course took its current form in 1991, but one of its main features, its flatness, remains, so visibility is limited. Today the Silverstone complex consists of two tracks: the main 3.19-mile (5.1-km) course, and a short 1.77-mile (2.8-km) course. Long straights and very fast, flat corners combine to make it hard to choose the right setup at Silverstone, with too much or too little downforce a major issue on different parts of the circuit.

Originally constructed in 1962 as a test track for Honda Motor Co., the Suzuka circuit has been the home of the Formula One Japanese Grand Prix since 1987. Its figure-eight layout with an overpass is surrounded by an amusement park with a giant Ferris wheel that looms behind the main grandstand. Suzuka challenges drivers with a variety of fast and slow, left and right turns, followed by sweeping high-g curves. With a course length of 3.6 miles (5.8 km) and sixteen turns, Suzuka is one of the longest, most complex circuits in international racing. The famous and very fast turn 130R, the series of fast esses, the slower Spoon Curve, and the final slow Casio Triangle chicane add up to a track that is technical and tricky—and very popular with drivers and race fans alike.

Track Specs:

Name:	Suzuka Circuit
Location:	Japan
Date opened:	1962
Length:	3.6 miles (5.8 km)

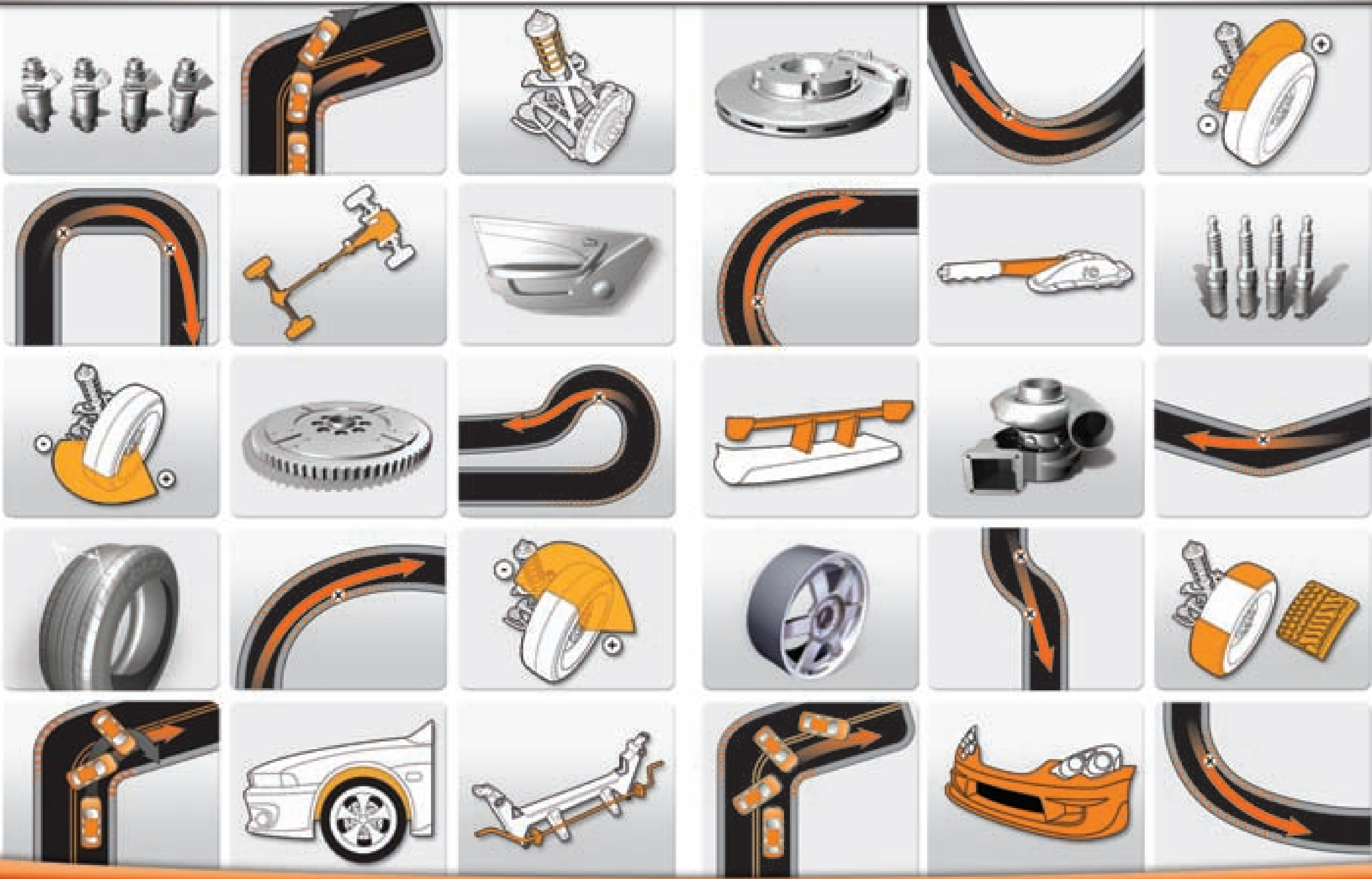
TSUKUBA CIRCUIT



Track Specs:

Name:	Tsukuba Circuit
Location:	Japan
Date opened:	1970
Length:	1.25 miles (2 km)

The short, tight, Tsukuba circuit was originally built for motorcycle racing in the 1970s, and offers unique challenges for drivers of fast cars. It packs twelve turns, including three hairpins, into just 1.25 miles (2 km), so good handling—and quick reflexes—are essential. A lap begins with the first of the three hairpins, which are connected by tight constant-radius turns. The last hairpin is especially critical because this sharp, banked turn leads onto the course's longest straight, which in turn leads to a sweeping high-speed turn to the finish line. This is a great course for C- and D-class cars, which may reach their top speed toward the end of each lap, but making a good time in faster, more powerful cars calls for the car setup and the driver to be in top form.



This short racing school introduces a number of topics you need to understand in order to be a successful competitor in racing, simulated or real. These topics include:

- Turn types, and which turns are really important for racing success
- Basic turn strategy
- Braking and cornering
- Managing weight transfer
- Making smoothness and consistency part of your race driving style
- Coping with—and tuning for—understeer and oversteer

As much as anything, the tips and techniques you'll see here are meant to get you thinking about what you're doing when you get your car onto a race track. A lot of this information sounds simple, but reading about it is one thing, while driving intelligently under the pressure of racing is entirely another.

Some Turns Are More Important than Others

Understanding the various turn types makes it easier to plan your strategy for getting good lap times around any track. Understanding that some turns are more important than others can yield even better lap times. While it's important to learn how to get through any turn efficiently, your ability to enter a straightaway at the highest possible speed and cover the length of the straight as quickly as possible is a key to racing success. You also need to develop the ability to set up the car so you can enter a turn at the end of a straight with the car balanced and ready for what follows.

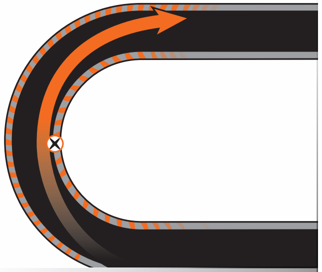
With all of this in mind, the most critical turns are the ones that lead onto or immediately follow a straight. Sometimes you need to treat a given turn as a "compromise corner," taking it more slowly and deliberately than you think you should in order to position your car perfectly for the turn that leads onto a straight. Similarly, you need to brake early enough at the end of a straight to enter the following turn with enough poise not to lose time by having to correct for overenthusiastic driving.

Turns: The Textbook Approach

The approach to any turn follows the standard practice of slow in, fast out. When you're taking a textbook approach to a turn, you brake (decelerate) going in, move to the inside of the corner, and then accelerate on the way out.

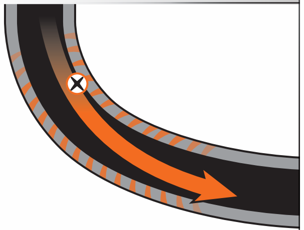
The X on each of the following diagrams is the apex. On an average turn, you decelerate before the apex and accelerate after it. The apex is on the inside of the corner, so you should take the shortest path through the turn. Remember, using the largest possible radius through a turn, following the line that requires the least steering, produces the fastest times. Most of the diagrams include a classic outside-inside-outside line. The line you take might deviate from this, but in these standard examples, determining your apex is fairly predictable.

TURN TYPES



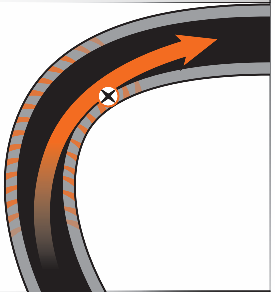
Constant Radius

In a constant-radius turn the apex is halfway through the turn.



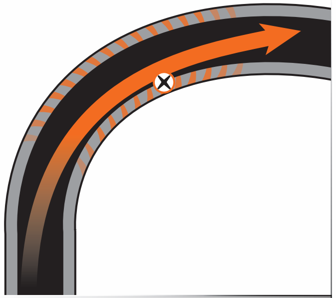
Increasing Radius

An increasing-radius turn is easier to take with an early apex.



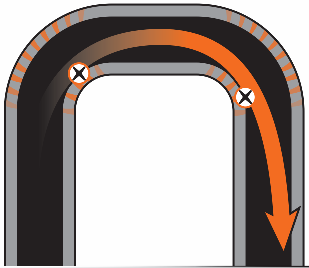
Decreasing Radius

A late apex often works for decreasing-radius turns.



Sweeper

A single apex works well with a textbook sweeper. Taking the widest arc, the line that requires the least steering, produces the best times.



Dual Apex

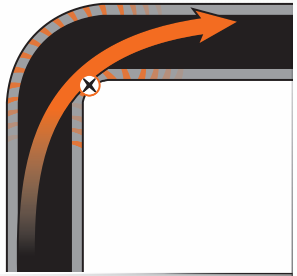
Some turns are long enough that you use two apexes to get through them.

Kink

A kink counts as a turn, but it's so slight that you may not need to plot an apex at all. You can either brake lightly, decelerating before the apex, or bolt through on a fast-in, fast-out line.

Hairpin

Hairpins can be tricky, but with practice, you can use a late apex to exit at a higher speed.



Right Angle

Under ideal conditions, you can smooth out a right-angle turn by using a standard outside-inside-outside approach. Even if the turn isn't exactly ninety degrees, the strategy is the same.

Chicane

Look for the straightest line you can find through a chicane sequence of turns. You may not need to decelerate and accelerate through each apex.

There is a standard approach for every type of turn, but you'll probably deviate from it based on your driving style. Deciding how much you want to deviate from the Suggested Line, or from the textbook approach to a turn, is a good place to start when thinking through a strategy. Some drivers do this intuitively, but when you're trying to shave seconds off your lap time, a little planning never hurts. When a track has several turns in quick succession, how you leave the first turn sets up your approach to the second—which makes having a plan for the lines you take even more important.

When you're ready to use your turn strategies in races online, other cars will prevent you from taking an optimal line on each turn, but you can use similar tactics when you're dueling with another car through a tricky part of the course. Knowing where another driver wants to be is part of knowing how to slow him down—without bumping him or knocking him off the track.

Planning for the Road Ahead

When you set out to master a new track, give some thought to the line you want to take through each series of turns. When you exit a turn, do you want to set up on the inside or outside? Will your exit from the last turn affect your setup for the next one? Drivers who plan ahead always have an edge over those who just react to the road.

Understanding the different turn types is an important first step for beginning drivers to improve their skills. After you've been driving for a while, it can help you attack a track without using the Suggested Line. For all *Forza Motorsport 2* drivers, thinking through different approaches for different types of turns adds a level of complexity to a game that's already very deep.

"During the race, try to drive a little faster than is enjoyable; you cannot go really fast without frightening yourself occasionally."

—Paul Frère, Sports Car and Competition Driving

The Suggested Line in *Forza Motorsport 2* makes learning to drive a car at high speeds much easier, but as you gain driving experience, you'll learn that your choices for taking a turn can vary from the Suggested Line. The day will come when you're ready to drive without it. Whether you're planning your strategy for a track or just looking for a challenge, practicing without driving aids takes skill—and some hard-won knowledge. Understanding braking and cornering basics will definitely help.

Using—or Not Using—Driving Assists

Forza Motorsport 2 goes out of its way to simulate the real-world physics of driving. In this simulation, every car has three driving assists that can affect how you brake and corner to make driving easier:

- Stability Control (STM) controls the attitude of the car when cornering.
- Traction Control (TCS) controls wheelspin, affecting how much traction is used to enhance acceleration and how much is used to assist in cornering.
- Antilock Braking System (ABS) prevents your tires from locking up under heavy braking.

In *Forza Motorsport* these assists are labeled **STM**, **TCS**, and **ABS** (usually near your speedometer), and they light up when those assists are in effect. Racing without driving assists is a good way to improve your driving technique, but it also takes practice—and strategy.

Knowing how to drive without these assists can reduce your lap times and give you an edge in online competition, and is an important step in developing a deeper and more satisfying approach to the game.

When you're in Career mode, you earn extra credit when you turn off any or all of these assists. In the online version of the game, the driver who sets up a race doesn't have the option of turning them off, but some race organizers look for competitors who voluntarily drive without them. All of the driving techniques discussed below become even more important when you turn off the driving assists.

Basic Braking Techniques

When you drive without your driving assists, there are two braking techniques you can use: straight-line braking and trail braking.

Straight-Line Braking

Straight-line braking is an easy technique to practice. As you're approaching a corner, you brake in a straight line, slow down until you're at the proper speed to turn in, and then drive through the corner. If you brake and turn at the same time, your tires can't use all of their grip on the braking maneuver. Instead, some traction is used to turn the car, and the rest is used for braking. This means you can brake more effectively if you use straight-line braking before you turn. This technique is easier to practice with the Suggested Line switched on—you just brake in a straight line until the guide turns yellow, and then turn into the corner. When you're driving without antilock brakes, braking without locking up is challenging.

Trail Braking

Trail braking often works better than straight-line braking on slow, tight turns. You start out braking in a straight line, but as the car slows down, you ease off the brake and carefully turn into the corner. At this point you'll be going slowly enough that you can turn safely, and the act of turning slows your car as you corner. If you're making a right turn with a steering wheel and pedal, think of a string leading from your foot on the brake up to your left hand: as the wheel turns in, it pulls the brake up. This maneuver is also easier to practice with the Suggested Line on. When you see red on the line, start braking. As the color fades to yellow, turn into the corner at the end of the maneuver for the last bit of braking.

"To operate at maximum efficiency, a driver should try and use all the space that's available to him: the full width of the road. … [Y]ou have to make the circuit as wide as possible, and sometimes a little wider, without damaging the car …"

—Alain Prost and Pierre-François Rousellot, Sports Car and Competition Driving

When practicing both of these braking techniques, you'll need to watch for brake lockup. It takes a while to sense when this is going to happen. One way to learn is by leaving your ABS on and turning the other two driving aids off. When your brakes start to lock up, ABS lights up, showing that the car has started to compensate for your braking. If you brake too hard, the locking brakes keep the front wheels from responding to your steering inputs. When you start practicing this technique you may even want to go to the Garage and soften your brakes a little. Using a force-feedback steering wheel like the Xbox 360 Wireless Racing Wheel can give you some advance warning when your steering is compromised.

If you downshift while you brake into a corner, you'll slow down your engine as you slow down your car. An advanced technique called "engine braking" involves downshifting without braking to slow down. It isn't easy, since downshifting at the wrong time will damage your engine. Done correctly, you'll slow down a little while shifting. Even if you don't use engine braking, you'll usually want to downshift going into the turn so you're in the right gear to accelerate back out of it, following the standard approach of slow in, fast out. With this technique, you'll have more torque coming out of a turn.

Watch for markers by the side of the road before or after turns when you are driving without the Suggested Line. Those little numbers by the side of the road are extremely useful for determining when to brake. If you can't find braking markers, memorize landmarks instead.

When you're braking and cornering, you must decide how you want to enter and exit each turn. In the "Turn Types" section of this guide, you learned the textbook apex for different types of turns, along with the standard approach for the nine basic turn types. Depending on what you want to do after the turn, you may want to deviate from that advice. For example, you may want to hit the inside corner of the turn a little early or a little late, using an early apex or late apex.

Using Early and Late Apexes

When you're cornering with an early apex, you're hitting the inside corner before the geometric center of the turn. The textbook approach to an increasing radius turn relies on an early apex. When you apex early, the line gives you more room to accelerate after the turn, which means you might reach a higher speed at the end of the turn.

A late apex involves a compromise. You're balancing your speed coming into the turn with your traction coming out of it. This gives you a higher average speed through the turn, which makes it a little easier to reach your top speed after it. This approach also works well on narrow turns and corners, where that extra traction makes it easier to get through a corner.

Intermediate drivers learn to find their own lines through a track, regardless of what the Suggested Line says. The best way to do this is by practicing without the line at a slow speed, and then applying what you've learned at a higher speed. If you hit the inside of the track before you want to turn, you're apexing too early, and may run off the outside of the track. Apexing late slows you down more than necessary going into a turn. When you're experimenting with different lines through a turn, use the entire width of the track on your way out.

When you're planning your strategy for a track, you may need to compromise your speed in certain sections. For a turn that leads onto a straight, keep your car at the highest speed you can manage through the turn so you can approach your top speed as soon as possible afterwards. If a turn is followed by a sequence of turns, compromise your speed so you enter the next turn at the right speed. Try to find the smoothest possible line between the apexes on a track, pushing to shorten the distance you need to brake on the way in. Remember, the line that requires the least steering is generally the fastest.

Slow In, Fast Out

Any corner you take has three parts: the entry, the apex, and the exit. A skillful driver slows down on the entry to an average turn, hits the right apex, and accelerates out of the turn on the exit. Some turns require you to brake in a straight line and then turn, while others work better if you can delay your trail braking until right before the corner. Most corners work best with a predictable apex, but you can adjust your speed and traction for the section that follows by cornering early or late.

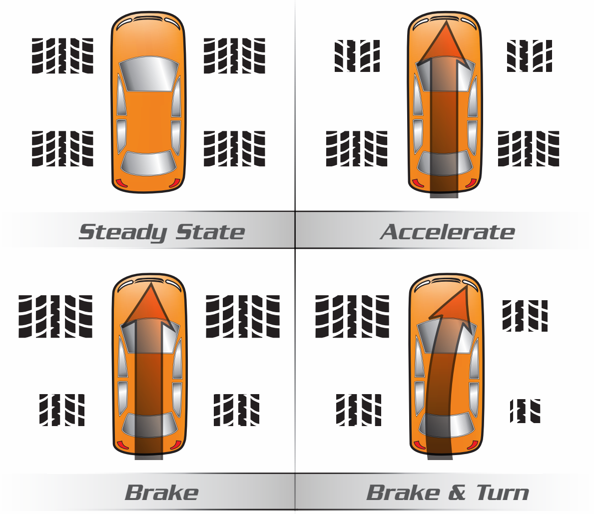
Now it's time to put theory into practice. Experiment on turns without the Suggested Line, pay attention to what happens when you try various approaches without driving assists, and get all you can out of your driving in *Forza Motorsport 2*.

"It is astounding the number of drivers who will just burn up the track through a [turn between other turns,] … thinking to themselves, boy, am I eating up these guys in front of me. And then lose all the ground they gained, and more, because they weren't in the right line to make a maximum-speed entrance onto the next straight."

—Alan Johnson, Driving in Competition

When you're sitting in a car at rest, or driving one in a straight line at a steady speed, the whole weight of the car is more or less evenly distributed on the four small patches of rubber where the tires contact the road. But when you're accelerating, braking, or cornering, the car's weight shifts backward, forward, or laterally. This weight transfer enlarges or reduces the size of each tire contact patch, increasing or decreasing each tire's traction. The greater the weight transfer at any given moment, the less overall traction the car has to work with. *Forza Motorsport 2* models these real-world weight and tire dynamics. And just as in real racing, it rewards your ability to manage them.

Racing, of course, consists entirely of accelerating, braking, and cornering in order to lap a circuit more quickly than the competition. There's a lot more to doing this successfully than jumping alternately on the throttle and brakes and cranking the steering wheel to get the car through corners. In racing, traction is life, and maintaining optimum traction makes the difference between being a front-runner or a back marker. As you'll see, the key is smoothness and consistency. Let's take a look at the effects of these actions on your car's traction and poise.



Acceleration, Deceleration, and Braking

Acceleration

The harder you accelerate, the more weight shifts to the rear of the car. As a result the rear end of the car squats downward, compressing the rear suspension and putting more weight on the rear tires, expanding their contact patches. The other side of the equation is that weight shifts away from the front tires, decreasing the size of their contact patches. This reduces front tire adhesion—and the car's response to your steering inputs. When the car is turning, this condition is called understeer. It is caused by the increased slip angle of the front tires, the angular difference between the direction the wheels are pointed and the direction of the tire tread. As you'll see below, you've got to limit and control understeer to make good lap times.

Deceleration and Braking

Deceleration, from lifting off the throttle or braking, has the opposite effect—the more abruptly you lift off the throttle and the harder you brake, the more weight shifts to the front of the car. The nose dives downward, the front suspension compresses, and more weight gets loaded onto the front tires, expanding their contact patches at the expense of reduced weight and decreased traction at the rear. Under hard deceleration, with most of the car's weight shifting forward, the lightened rear end has too little traction to keep the car balanced. If this happens while the car is turning, the car overreacts to even small steering inputs. This condition is called oversteer, caused by the increased slip angle of the rear tires. As you'll see, oversteer can get you into big trouble.

Cornering

Managing weight transfer is trickiest when you're cornering. As you enter a turn under deceleration and braking, the car's weight transfers not only toward the front, but also laterally, away from the corner apex toward the outside tires, so they have more traction. For example, entering a right-hand turn, weight transfers to the wheels on the left side of the car. In a left-hand turn the opposite happens, and the tires on the right side of the car carry more weight and have more traction.

Smoothness Is the Key

These textbook descriptions of weight transfer barely convey the reality of driving a car in race conditions. Under pressure, inexperienced drivers tend to lack finesse, alternately mashing the throttle and brakes, and jerking abruptly on the steering wheel. This can have disastrous effects on the car's balance just when you need it most. Even when you accelerate, brake, and turn smoothly, weight transfer happens. Stomping or abruptly lifting off the throttle, jumping on the brakes too hard, or jerking hard on the steering wheel exaggerates the effects of weight transfer, increases the tires' load sensitivity and decreases grip. Instead of unsettling your car and losing time, you may get completely out of shape and go for a damaging excursion off the track, possibly taking some of your competitors with you. The greater your car's performance, the more smoothness pays, and the more damaging rough driving is to your racing success.

The idea of driving smoothly while racing may seem counterintuitive. After all, you're surrounded by a pack of aggressive competitors, all of them trying to get around you. Your own desire to charge ahead of the pack encourages your own aggressive efforts. So who has time to be smooth? It takes discipline to keep your brain engaged under these circumstances, but how intelligently you drive is as important as your willingness to drive aggressively and take risks to improve your position on the track.

Remember that accelerating, decelerating, and turning smoothly doesn't mean doing these things slowly. Doing them right helps you to be fast and keeps you out of trouble. So how do you go about it? It all begins with what fighter pilots call "situational awareness"—not just being aware of everything that's going on around you, but also being sensitive to how your machine is responding, and its overall balance in every situation.

Mixing Delicacy with Aggression

Keeping your car poised to perform its best on every part of the track requires you to mix delicacy with aggression. You still get onto or back off the throttle when you need to, brake as hard as you have to, and turn the wheel to extremes as necessary, but you don't do any of these things all at once. Instead you ease onto or off the throttle, gradually add or reduce brake pressure, and steadily feed in steering input so that you remain aware of the way the car's shifting weight is affecting its overall traction and balance.

The benefit of this approach is to minimize the unsettling transient effects of weight transfer. The main consequence if you can't master this smoother style is that you can fall into a vicious cycle of overcontrolling the car, then overcorrecting to try to stay in shape on the track. Each part of the cycle gets worse, and you find yourself battling your car instead of your opponents.

For example, accelerating hard and then abruptly lifting off the throttle and getting on the brakes throws the weight of the car back and then forward. The harder and faster you do it, the more exaggerated the effect. First the weight on the front wheels lightens and steering input becomes less effective, then you unload the rear wheels, lightening the back end of the car. If you jump back on the throttle you only amplify these effects. Similarly, jerking the steering wheel leans the car over, putting too much weight on one side and too little on the other. A yank in the opposite direction makes the car even more unstable as the weight abruptly shifts in the opposite direction. The net effect is to keep the car from settling into the best-balanced attitude for what follows, and you find yourself watching as better drivers leave you behind. At worst, you're not just struggling to catch up, but you're so unbalanced and out of shape that you're either off the road or in the wall.

A Consistent, Seamless Approach

Nothing you do is done in isolation. On every lap, no matter what the racing situation, work to develop a consistent approach to every part of the track and to what comes next. Instead of reacting from moment to moment, think strategically about how to improve your lap times. You want to stay near your car's limit of adhesion all the way through each lap, and you can only do this by striving for a seamless flow from acceleration to deceleration to braking to cornering and back to acceleration. Your lap times and race results will steadily improve as this consistent, seamless driving style becomes more reflexive.

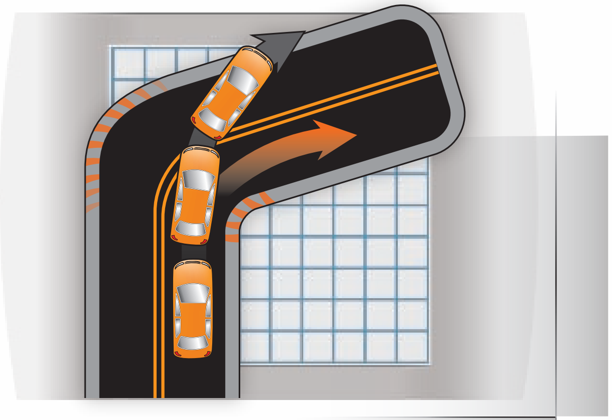
COPING WITH UNDERSTEER AND OVERSTEER

We've talked about understeer and oversteer as consequences of heavy acceleration and deceleration, but even if your driving is a model of smoothness and consistency, the way your car's chassis is tuned can induce or aggravate these conditions. In *Forza Motorsport 2*, you can tune your chassis setup to balance your car's tendency toward understeer or oversteer.

Taken to extremes, both conditions have an adverse effect on a car's handling. However, controllable amounts of understeer or oversteer may be desirable, depending on the kinds of corners that are most important on the circuit you're lapping. For high-speed corners, tuning the chassis to induce mild understeer is a safe approach that can spare the driver some unpleasant surprises. For slow, tight corners, tuning for mild oversteer helps the driver get through them efficiently, without a lot of steering input.

Understeer

Understeer occurs when a car's front tires have less adhesion than the rear tires. When you enter a turn in an understeering condition, the car is less responsive to your steering inputs, and tends to continue in a straight line, toward the outside of the turn. This can help you in fast turns, but can force you to wrestle the wheel around in slow turns.



Understeer

Careless Acceleration or Braking Can Cause Understeer

Let's review a bad way to induce understeer even if your chassis is tuned to avoid it. The harder you accelerate into a turn, the more weight shifts from the front of the car to the rear. This decreases the front tires' contact patches and reduces their traction, causing understeer. No matter how much steering you feed in, you may not make it through the turn ahead of your competitors.

Braking while turning can also cause understeer, especially with ABS turned off. Some of your traction helps turn the car, but the rest is used for braking, which reduces steering response. Remember, you can brake more effectively if you use straight-line braking before you turn.

No matter how carefully you tune your chassis setup, if smoothness and consistency aren't important parts of your driving style, you'll find that you've wasted a lot of time and effort.

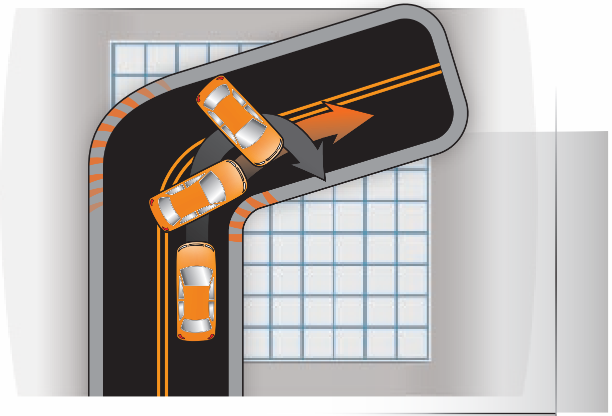
Correcting for Understeer

If you've accelerated too hard or suddenly into a corner, or entered one at too high a speed, or compromised your steering by braking while you turn, or locked the front wheels, you'll find yourself trying to negotiate the turn in an understeering condition. Your instinct will be to add steering input to get the car to go where you want it to—and this is a mistake. Adding steering in this situation increases the front tires' slip angle, which increases understeer.

Of course, if you brake intelligently and reduce your speed so you enter the corner at the right speed, and ease the throttle to transfer sufficient weight to the front of the car, you won't have to deal with understeer. But if you do get yourself into this situation, you can deal with it by reacting smoothly and with sensitivity to what the car is doing. When you enter a turn with understeer, decrease your steering input a little, modulate the brakes to unlock the front wheels, and gently ease off the throttle to transfer weight to the front of the car. This will reestablish your front tire traction, so you can ease back onto the throttle and continue on your way. You'll lose a little time doing this, but you'll also be in a better position to get back into the race. Using a force-feedback steering wheel like the Xbox 360 Wireless Racing Wheel helps you to detect understeer by markedly lightening steering effort.

Oversteer

Oversteer occurs when the car's rear tires have less adhesion than the front tires. When you enter a turn in an oversteering condition, the car tends to overrespond to even small steering inputs, so it tends to turn more than you want, toward the inside of the turn. This can make it easy to get through slow, sharp turns, but it can be dangerous in fast turns.



Oversteer

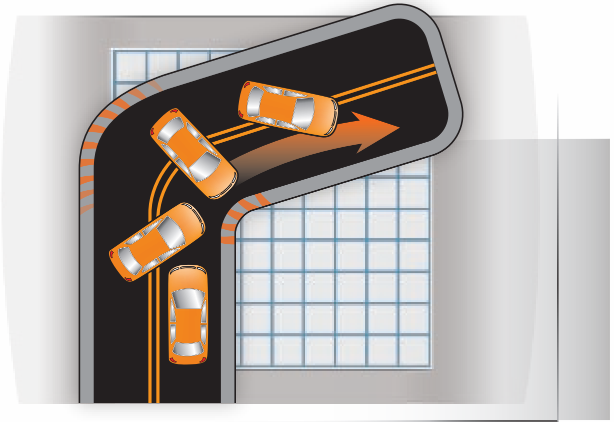
Careless Deceleration or Heavy Throttle Can Cause Oversteer

As noted earlier, the more abruptly you lift the throttle and the harder you brake, the more weight shifts from the back of the car to the front. This decreases the rear tires' contact patches and reduces their traction, making the back end of the car loose and causing oversteer. While this may help you to get around slow, sharp turns more quickly, it can catch you out in fast turns, with the car reacting too much to even small steering inputs, so the rear end breaks loose and you lose time, or spin.

If you're driving a powerful rear-wheel-drive car, you can use the throttle to induce "power oversteer" to help rotate the car. Too much throttle can result in a spin, but the right amount can be very rewarding.

Correcting for Oversteer

Oversteer is trickier to deal with than understeer, and its effects can be more sudden and more vicious, but you can deal with it if you keep your head. If you've braked too hard, or abruptly lifted off the throttle entering the turn, or added too much throttle while turning, you'll find right away that you're dealing with oversteer as you try to get through the turn, with the back end sliding out from under you and the car pointing toward the inside of the turn. Adding still more throttle may seem like a good idea, but it's not. It will spin the rear wheels and you won't be able to reestablish their traction. To correct for power oversteer, you must gently reduce power before adding more steering input.



Oversteer Correction

To reverse the effects of oversteer and reestablish control, you have to ignore your instincts and respond intelligently, and counter-steering is the key. First, turn quickly but precisely into the slide to increase the radius of the turn and carefully ease the throttle. If you yank your foot off the throttle, you'll lose rear traction and spin off the track. If you do it right, this should straighten the car out, and you've got to wait for it to happen. As it does, straighten the steering, then ease on a little more throttle to settle the car and reestablish rear traction. It sounds simple, but it's not. Only practice and experience will make this process easier and more reflexive. Again, using a force-feedback steering wheel like the Xbox 360 Wireless Racing Wheel can help you to feel when you are providing the right amount of counter-steering input.

Keep in mind that the sudden onset of extreme oversteer may be uncontrollable, and you have to recognize when you can't correct for it. If you're sure you can't save the situation, get onto the brakes hard, and get the car stopped before it carries you into an even worse situation.

Chassis Tuning for Understeer and Oversteer

Many production cars' chassis are set up to produce mild understeer because this is a safe, predictable mode for most drivers. Higher-performance cars and purpose-built race cars are often set up with neutral steering in mind, not leaning markedly toward under- or oversteer unless the nature of the race track makes one or the other desirable.

In *Forza Motorsport 2*, you can tune your chassis setup—including tire pressure and alignment, suspension stiffness, brake balance, and the differential—to reduce or increase understeer or oversteer, but you have to be careful. Tuning is tricky and can have unintended consequences. When you change your chassis setup, test drive your car to see the effects of your changes before you race. You may have to tweak your settings repeatedly to get the results you want.

"Smoothness takes a lot of self-discipline. But smooth is fast, and smooth is safe. … If you want to race, smoothness is helpful … if you want to win, it's essential."

Concentration + Technique + Precision + Consistency = Smoothness.

—Bob Bondurant and John Blakemore, Bob Bondurant on High Performance Driving

An Interview with Racing Driver Gunnar Jeannette

Racing school wouldn't be complete without some insights from a driver who races for a living. Team Panoz driver Gunnar Jeannette has been a successful competitor in professional racing since 1999 in Le Mans Prototype and sports racers. He has been in the thick of competition at Le Mans, Daytona, Sebring, Laguna Seca, Mosport, Lime Rock, Watkins Glen, and other famous tracks.

Q: Paul Frère says that you can't "go really fast without frightening yourself occasionally." Do you agree?

I agree. As a driver you have to be constantly pushing yourself. With that comes what we call "moments," when you almost have a big wreck. Sometimes in order to go faster you must just suck it up and ignore the sane little voice in the back of your head saying that you shouldn't be trying to take this turn flat out, or without braking, or in fourth gear, or whatever. It may work and it may not, but as a driver you must test the limits and rely on your ability to get yourself and the car out of the situation alive.

Q: What's the funniest experience you've had as a race driver?

The funniest on-track experience I've had was during 2001 Le Mans when I ended up finishing second in the GT class. It was the middle of the night, raining really bad, and at that time of night you're almost driving around by yourself because the track is so long and quite a few of the cars had crashed out due to the rain. Anyway, for some reason the Tone Loc song "Funky Cold Medina" got into my head, and for a few laps I was singing it to myself. I'm laughing to myself right now even thinking about it. I have no idea how that song got in there, but I vividly remember cresting the famed Mulsanne hill and rocking out to that song.

"Racing is a very hard sport to be successful in at the top level. People don't understand the amount of skill, money, luck, and determination that it takes to get to be a pro and stay there. It's a cutthroat sport and you have to stay on your game all the time. It's a sport that's easy to love and hate at the same time."

Q: How do you deal with contact between cars?

Contact between cars is something that happens in all forms of racing. In sports car racing it tends not to happen much, at least deliberately, because our cars tend to be very expensive and parts are built as light as possible. But contact does still occur, especially between the different classes of cars because the speed differential can be so high. The most important thing is to try to manage the damage. If you know what the vulnerable parts of the car are and can avoid any sort of contact in those areas, you'll be much better off. But sometimes it's inevitable, and somebody's going to get hit!

Q: What is your favorite track to race on? Why?

Le Mans for sure is my favorite event of the year. There are so many people who come out and know all the drivers and teams, which makes it very crazy and fanatical. The track is a blast to drive, very fast and super challenging. Not to mention that the race has been going on for over seventy years, and it's where our type of racing originated. One of the coolest things about the weekend is the drivers' parade that takes place on the Friday before the race. All the drivers ride in historic Bentleys, Citroens, Renaults, and other cool old cars, and we get driven through the center of town in about a three-mile loop in front of over one hundred thousand people. It's a real trip to see all those people screaming for autographs and hero cards.

Q: How do you handle the start of a race?

You can never really plan the start of the race. A lot of times I'll try to think of all the various situations that could happen and try to have a couple of options for each. Even then, most often something happens that I never could have thought of. Sometimes it's best to take it a bit easy at the start and make sure that you get through in one piece, and other times you know that you must get ahead or stay behind someone or there will be a bad shunt. The most important thing is to get the car to the finish!

Q: What can you tell would-be racers to help them understand what they're up against?

Racing is a very hard sport to be successful in at the top level. People don't understand the amount of skill, money, luck, and determination that it takes to get to be a pro and stay there. It's a cutthroat sport, and you have to stay on your game all the time. It's a sport that's easy to love and hate at the same time.

Q: Are there lessons about racing you had to learn the hard way?

There are a lot of lessons I've had to learn the hard way. It's easy to listen to people talk about not doing something stupid and say, "I'd never do that." But when you're presented with that situation, doing the right thing can be difficult. There's just something about crashing a car that seems to iron the lesson into your subconscious.

Q: Who are your racing heroes, drivers who inspired you as you were getting your career started?

I had a lot of racing heroes as a young kid. My father restores historic Porsche race cars and was a crew chief on sports car teams that won Daytona, Sebring, and several other races while I was growing up, so it was easy for me to look up to those people. For instance, Derek Bell, Brian Redman, John Paul Jr., and Bob Wollek all drove for my father at one point or another, so I had many great drivers to look up to and get advice from as I started racing.

Q: What is your advice for successful passing and on keeping from being passed?

It's all about knowing your strengths and weaknesses as well as those of your opponents. For instance, if my car isn't too good exiting a certain corner, I'll make sure that mid-corner I slow down enough to bunch my opponent up and ensure that I get a good run out of that turn and he has over slowed to where he can't do anything by the next turn. Similarly with passing, if you can work on the guy ahead of you and get him worked up to make a mistake, then you can make your move.

Q: Do you use computer racing simulations or games in your preparation for a race?

I do use simulations in preparation for some races. I don't use them on the day-to-day tracks or races that we visit frequently, but if I'm going to a new track, I can do many laps on a racing simulation so I won't use up valuable time having to learn the track in the real race car. If I haven't been somewhere in a while, it's nice to reacquaint myself with the place before showing up.

Q: Most Forza Motorsport 2 drivers have no real racing experience, but they have a lot of enthusiasm. What advice would you give beginning sim racers to help prepare them for racing success, simulated or real?

The best advice I can give to beginning racers is simply to watch and listen. Ask questions, but try to find the people who really know what they're talking about. There are a lot of people out there who like to listen to their own voices and don't really understand what's happening. Be patient and don't be afraid to make mistakes—just try to avoid the big ones!

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